In presenting the dissertation as a partial fulfillment of the requirements for an advanced degree from the Georgia Institute of Technology, I agree that the Library of the Institute shall make it available for inspection and circulation in accordance with its regulations governing materials of this type. I agree that permission to copy from, or to publish from, this dissertation may be granted by the professor under whose direction it was written, or, in his absence, by the Dean of the Graduate Division when such copying or publication is solely for scholarly purposes and does not involve potential financial gain. It is understood that any copying from, or publication of, this dissertation which involves potential financial gain will not be allowed without written permission.

7/25/68

A COMPREHENSIVE CLINICAL HEALTH TEAM COMPOSITION AND FACILITY EVALUATION

A THESIS

Presented by

The Faculty of the Division of Graduate

Studies and Research

by

Pierce

David Mason

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Industrial Engineering

Georgia Institute of Technology

September, 1970

A COMPREHENSIVE CLINICAL HEALTH TEAM COMPOSITION

AND FACILITY EVALUATION

Approved:

Chairman

Date approved by Chairman: Dec 18, 1970

TABLE OF CONTENTS

ACKNOWLEDGMENTS

Appreciation is expressed to the committee chairman, Dr. Gerald L. Delon, for his invaluable assistance and direction, and to Dr. D. C. Montgomery and Dr. S. L. Dickerson for their contributions. Recognition is given to the administration and staff of the Atlanta Southside Comprehensive Health Center for their participation in this study and to Dr. J. Harrison of the Health Systems Research Center for his support. All have given of their personal as well as professional time, without which the study could neither have been made nor reported.

Deep thanks are due to the author's wife for her assistance and understanding, to Mrs. N. E. Ceruli and Barbara Conner for the manner in which the manuscript was typed, and to the Health Systems Research Center of Georgia Institute of Technology for its financial support.

These persons and many others have provided the encouragement and understanding necessary to the completion of the study.

SUMMARY

The purpose of this study was to indicate the probable patient through-put volume potential at an OEO center such as the Atlanta Southside Comprehensive Health Center of the current facility and patient service sequence as compared to certain alternative facility arrangements and patient service sequences. Current procedures were obtained by observational studies and from such recorded data as could be found at the center. Data concerning the prospective alternatives were obtained by means of a questionnaire which was sent to every professional member of each team then working at the center.

An effort was made to use the Delphi technique to refine the questionnaire data since such data could only be based on the best insight of the team professionals. This effort was only partly successful in that only 13 per cent of the respondent group replied to all three requests for questionnaire data. However, the estimates thus obtained were found to agree, in general, with the estimates found on the 97 per cent return of questionnaires. Trends were at this time found to be clear and a fourth attempt to further refine the data by use of the Delphi technique was not made.

Two computer models based upon the concepts of the two medical unit patient service sequences were developed and programmed in GPSS II simulation language. Factors included consisted of the team membership associated with each

sequence and the critical patient routings and the service associated with various aspects of patient service. Three alternative provisions for numbers of examination rooms per unit were also included in the models. The models were used in (3 x 2) fixed factor factorial experimental design for the evaluation of the various sequence and room alternative combination effects upon patient volume through a medical unit.

Results of the study indicated that the proposed changes had statistically significant advantages over the current procedure. However, when these advantages were converted to actual numbers of patients who could be served by the several proposed changes in procedure as they would affect the center, the difference represented only a small numerical advantage which could easily be obtained by full use of current personnel and facilities.

While the immediate use of the format which has the greatest patient service potential seems of little real value, the expected increase in numbers of patients to be served as the center reaches the known available patient clientele indicates a real as well as practical use. The current free time of professional team members cannot meet the needs of a large numerical increase in numbers of patients to be served. The advantages offered by the proposed changes can provide an initial volume increase of ten per cent without the addition of physician staff members. The long range value of the study is evident in that it provides a means of indicating increased patient volume without the use of additional physicians who are already in short supply.

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

1.1 Historical Setting of the Problem

During the last two decades the health problems of this nation's low income or poor population have been receiving an ever increasing amount of attention. Many socio-economic factors have combined to cause large numbers of these low income persons to move into urban area slums far more rapidly than either private or governmental health services could (or would) follow. At the request of municipal governments, and with the support of Congress, the Federal Government has initiated a number of programs aimed at alleviating the health problems of the nation's poor in general and more especially those located in urban areas.

General programs, such as Medicaid and Medicare, provided some assistance to the poor. However, two trends have largely negated the value of these programs insofar as the urban poor are concerned. First, the medical personnel serving the urban areas before their deterioration into slums would not have been sufficient for the higher population density characteristic of a slum. There were, in fact, fewer medical personnel in that many of them moved from the developing slums to suburbia where practice remained more lucrative and was accompanied by an improved social environment.

For these same reasons, other medical personnel have been reluctant to replace their colleagues who have migrated from the slum areas. Second, the average cost of medical services as well as the percentage of individual income expended for medical services has risen steeply in recent years for all economic groups but for the urban poor to an almost prohibitive level, even with the assistance offered through both Medicaid and Medicare. Simply stated, the result of these trends has been that very low income populations within urban centers of the nation are served by too few medical professionals. Such medical service as is available suffers from a general lack of organization, which except in situations receiving massive funding has neither the personnel nor the facilities sufficient to provide an organized framework for health services to the poor.

In an effort to deal with the growing health problems of the urban poor, the Office of Economic Opportunity (OEO) has established neighborhood comprehensive health centers in selected urban low income, poor housing neighborhoods. These centers serve two important purposes: (1) They provide medical attention to the poor who live within a designated service neighborhood. (2) They provide an organizational structure for health care delivery which tends to improve and increase this medical attention in an economic way.

For the most part, the established centers have used a type of team approach for the delivery of health care which involves the association of a permanent team of medical personnel with a service neighborhood. The team approach provides the patient a physician and a definite set of medical personnel to identify with--something which most may never have had before. The division of a center's service neighborhood into team service neighborhoods provides the medical team with a fixed patient clientele which it can serve on a more personal basis than is possible with an undefined population. It is within the framework of the team approach and a defined service community that health center staffs seek innovations which can improve both the quantity and quality of their services.

The creation of the initial OEO sponsored community comprehensive health centers and their proliferation has added to the ever increasing demand for medical personnel, especially for physicians. Since the general national demand for physicians far exceeds the supply, it is quite evident that those available should be used as effectively as possible. Innovations which would increase the number of patients seen and served by the medical teams of OEO sponsored health centers without increasing the physicians' work load have the decided priority over approaches which alleviate, in part, the increasing demand for physicians. In an effort to meet this need, this study has been made using as a study site one OEO center, the Atlanta Southside Comprehensive Health Center (hereafter referred to as ASCHC). The ASCHC, one of the first three such centers in the nation, was the only center within 900 miles of the researcher and was following a team format common to all three.

1.2 Objective

The objective of this study is to evaluate the effects of adding a specially trained nurse (also referred to as nurse-practitioner, see definition of terms) to the sequence of the medical team personnel serving patients, and of varying the number of examination rooms per medical unit, both to be evaluated with respect to the number of patients seen. A comparison is made of the current patient flow within the team medical unit setup being used by the study site with a different flow pattern involving the use of the nurse-practitioner (which is being considered by the professional staff of ASCHC as a means to increase the number of patients seen and served by a health team medical unit). This study also includes the evaluation of both flow patterns, with and without the nurse-practitioner, varying the number of examining rooms. These two variables, patient flow pattern and number of examining rooms, are considered as they singly and in combination affect the number of patients that a health team medical unit serves.

1.3 Definition of the Problem

The specific problem attacked in this study is how to evaluate the expected effect that the addition of a specially trained nurse and variations in the number of examining rooms would have upon the number of patients served by a health team of an OEO community comprehensive health center. The newness of the OEO's involvement in the health field is, in part, a cause of the sparsity of relevant data concerning service delivered at OEO centers or at health centers with similar formats. Trial and error approaches, unskilled persons who are trained on the job, and poorly defined procedures for record maintenance combine to reduce the reliability of available data. In addition, the rapid growth of these centers, the fluctuating increase of patient loads, and the addition of medical personnel to the OEO health centers have necessitated changes in procedures. These factors have combined to produce data which is representative only of unstable growth.

By the use of simulation, however, systems such as these can be evaluated in a hypothetically stable state even though such a stable state may not exist in reality for several years. This can be accomplished by using models of the systems under study as they are conceptually expected to exist in the stable state and by selecting sufficient data from the real world systems to use in the development of an appropriate model for study. The fact that data from the real world environment of an OEO health center are largely incomplete for use in a simulation approach necessitates the location of an alternative source of data.

The limitation cited above is somewhat overcome by the expertise and experience of the professional staff of an OEO center. They collectively represent many years of experience in the field of health care delivery. Each member, as a result of both training and experience, possesses a high degree of proficiency in the methods and procedures of delivering health care. The education and experience of the members of a center's professional staff acting as a whole are comparable to a panel of experts. With proper organization, they can bring much insight and intuition to the evaluation of not only the immediate problem, but also of future problems.

In view of the fact that existing data have been considered both too scarce and too unreliable to be used to make valid evaluations of innovations for delivering health care, it appeared reasonable to incorporate into the evaluative procedure the collective intuitive powers of judgment which a center's staff possesses. The basic problem was to develop the organized methodology which would make this possible. If health care delivery innovations can be satisfactorily evaluated before installation by utilizing an OEO center's professional staff's intuitive judgments in the evaluation, then it may be possible that other health delivery mechanisms could perform similar evaluations.

1.4 Method of Procedure

The current patient flow (referred to as sequence one) which is evaluated is as follows: The new patient is interviewed by a clinical assistant who takes his medical history and records such vital signs as blood pressure, temperature, pulse rate, height and weight, and informs the physician that a patient is ready for examination. Should the patient be a repeat or an appointment patient, the medical history is merely updated and vital signs recorded prior to informing the physician. Second, the patient sees a physician who examines him and makes recommendations based on a diagnosis. Following the examination by the physician, the patient is returned to the clinical assistant who will explain the physician's instructions to the patient and release him.

A different flow pattern (referred to as sequence two) was identified by the researcher with the assistance of discussions with members of the professional staff of the OEO center. The patient flow sequence which was identified differs from the existing flow pattern in one major detail: the addition of a nurse-practitioner between the clinical assistant who prepares the patients and the physician who examines the patients. The nurse-practitioner conducts a brief screening diagnostic examination to determine if the patient's medical problem or problems may be diagnosed and/or treated by the nurse or if the expertise of the physician is required for diagnosis and treatment. Should a patient's problem need the expertise of the physician, the nurse-practitioner makes the referral. If not, the diagnoses and treatments are completed by the nurse. In either case the patient flow ends with a clinical assistant who explains the treatment and processes the patient out of the team area.

Each unit of the OEO center, the adult and the pediatric, is assigned a nurse-practitioner, thereby increasing the professional membership of each team by two. It is important to note that this plan makes it possible for the clinical assistant to refer a patient directly to the physician at such times as the nurse-practitioner is occupied treating a patient and the physician is not. It is also important to note that in this sequence the recording of medical history is not done by the clinical assistant preparing the patient, but is included in the screening examination or is done by the physician if the patient is routed to the physician without being screened.

The rationale for the addition of the nurse to the medical unit as a basic screener and diagnostician is that both the quality and quantity of patient care may be affected favorably. By limiting the treatment of readily diagnosable and treatable medical problems to the nurse, the physician may be able to allow additional time for the diagnosis and treatment of more difficult medical problems with the net effect possibly being an improved general quality of care. By providing an additional possible route through a team medical unit, the quantity of patients who can be processed by that unit may be affected favorably.

The two sequences described above may be viewed as a series of functions, queues, and decision points. The two patient flow sequences are conceptually described by the flow diagrams shown in Figure 1. Each rectangle represents a time

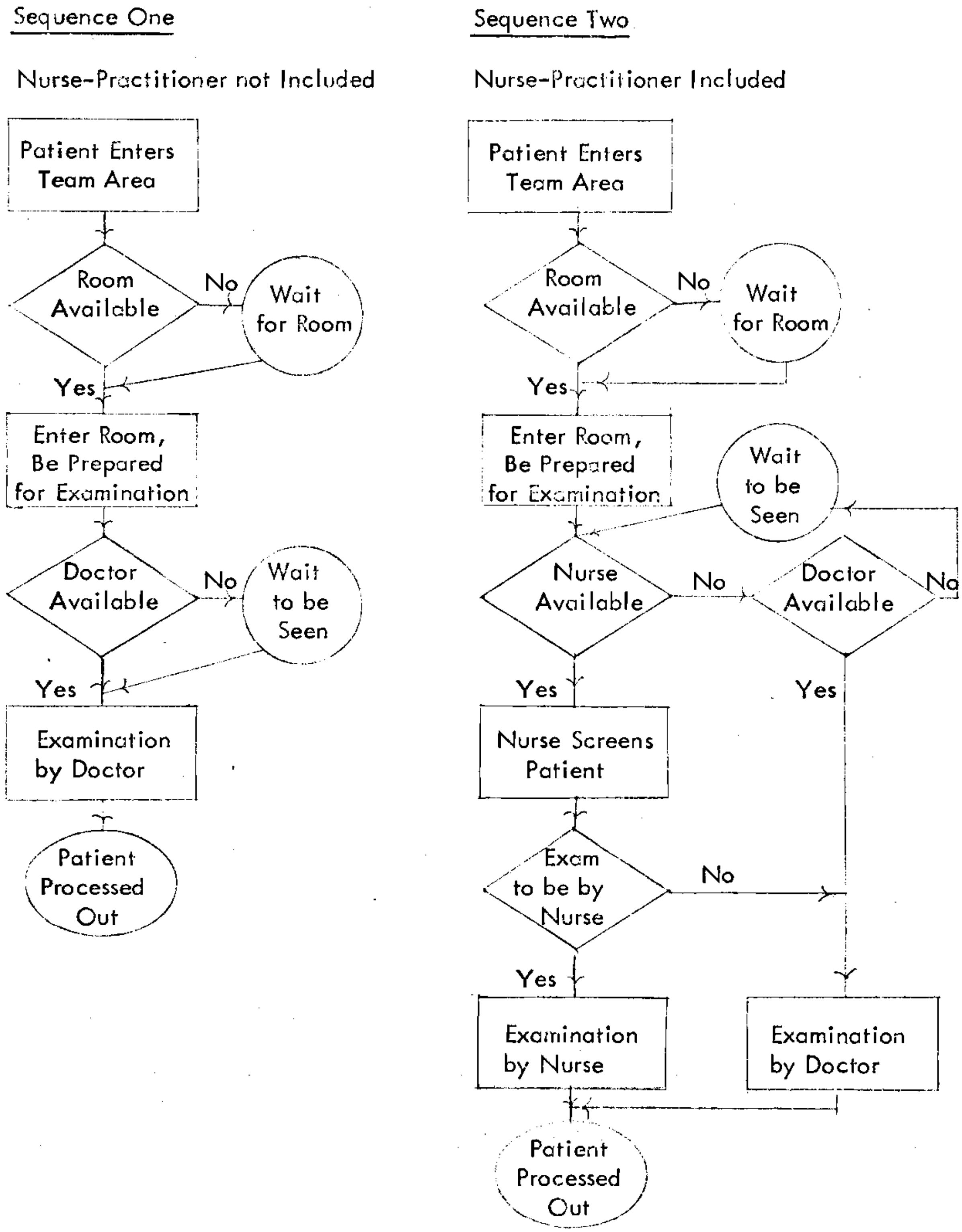


Figure 1. Conceptual Patient Sequence Flow Diagrams

related service function; each diamond represents a decision point; and each circle represents a queue.

Since under either patient flow sequence the number of examining rooms is a probable factor in determining its efficiency, this factor was included for consideration. Efficiency was determined primarily as a function of the probable number of patients which a medical unit operating under either sequence could serve, given a certain number of examining rooms. Of the several alternative numbers of examining rooms, three alternatives have been chosen for the purposes of this study and are as follows: (1) two rooms each per section (the current arrangement), (2) three rooms per section, and (3) four rooms per section.

Two classes of patients have been identified for purposes of this study and are as follows: (1) walk-in patients--those patients who are examined by the medical unit personnel but who did not arrange for an appointment before arriving on the premises, and (2) appointment patients--those patients who are served by a medical unit by virtue of having an appointment.

Two classes of patients do not follow either flow pattern and were not considered. These were emergency patients and those walk-in patients who are not seen by a medical unit but sent to another area of the center or given appointments for another day.

The evaluation of these alternatives was accomplished by a comparison using the framework of a factorial design. Computer models of the two patient flow patterns shown in Figure 1 were used to generate the data for the above comparisons. A modified Delphi technique was used to incorporate the intuitive evaluative powers of the ASCHC professional staff in the determination of certain input parameters for the computer models. Such applicable data as could be collected from the study site were also used in the computer models.

The specific procedure utilized to accomplish the comparison is as follows:

1. An OEO sponsored community comprehensive health center was selected as a study site. This was done to facilitate research since, at the time the research was being conducted, only three such centers were operating. One was located in New York, another in California, and the third, ASCHC, was located in Atlanta. The format of these centers was similar in that all employed a team approach as directed by OEO guidelines. The Atlanta center, ASCHC, was selected from the three as the single study site.

2. A review of the literature pertaining to the following was made:

   (1) Methods of studying the relationship between the patient, physicians, and facilities including the use of systems analysis and computer simulation techniques as approaches, and (2) the Delphi method of eliciting and refining opinions of experts.

3. The collection and evaluation of data:

   A. An analysis of records was made to determine the arrival patterns for pediatric and adult appointment patients as it related to the time of actual appointment. Data were also obtained concerning the "time of day" arrival distribution of walk-in patients. These data were collected for use as the expected arrival patterns for the alternative systems.

B. All comprehensive health teams at ASCHC were observed. The observation was conducted during the last three weeks of November, 1969. The observations were used for the following purposes: (1) to analyze the then current physician-patient time relationships for both the team pediatrician and the internist. Data collected was used to gain insight into ASCHC, and (2) to determine certain service times associated with the processing of patients through a medical unit. These were used as input parameters for the computer models.

C. The intuitive evaluation powers of the ASCHC professional staff were incorporated into the evaluation procedure by means of a modification of the Delphi technique of obtaining group concensus. (The technique utilizes a series of responses refined by feedback in the form of group response statistics from previous responses.) The modified Delphi method was used as a means to describe, define, and measure the effect of selected staff changes and facility arrangement on the physician-patient-time relationships. Respondents were asked to react to two different patient-flow patterns and three different facility arrangements as they singly and in various combinations affected patient volume. (The respondents were all of the medical personnel of ASCHC and were considered to form a panel of experts.)

D. A model was developed incorporating the basic concepts as interpreted by the researcher and members of ASCHC professional staff involved in the two patient flow sequences being considered. The model was divided into two sections, one corresponding to sequence one and the other to sequence two. The general characteristics of the medical unit service system and the distributions obtained from steps A, B, and C were then incorporated into these basic models. The complete models were programmed in GPSS II computer simulation language.

E. The computer model resulting from step D was used to create data to evaluate through a (2 x 3) fixed factor factorial design the two patient flow sequences and the three examination room alternatives with patient throughput volume as the prime criterion. The factorial design suggested a two-way fixed factor analysis of variance (ANOVA) to investigate the general effects of sequence and room as well as any interaction. Pediatric and adult medical units were evaluated separately since both the patients and personnel associated with each type of unit were unique. Duncan's Multiple Range Test procedure was used after ANOVA to investigate the significant relationships between cell means. Duncan's procedure enabled the nature of the ANOVA results to be investigated to gain an indication as to the relationship between sequence used and probable patient volume, and the specific relationship between numbers of examining rooms (two, three, or four) and probable patient volume. Of the many available procedures, Duncan's was selected as being most appropriate for use in a study of this nature.

1.5 Hypotheses

The following hypotheses were tested as a part of the study of the data collected in this study:

1. The mean number of patients which can be served in the current sequence differs significantly from the mean number of patients which could be served in the proposed sequence within any of the three numbers of rooms provided for either health team medical unit.
2. Each of the facility provisions studied differs significantly from either of the other two in mean patient through-put within either of the two sequence alternatives.

1.6 Scope and Limitations

This study was limited to two patient flow sequences. The first was the sequence concept currently being used at ASCHC in which the patient sees in sequence a clinical assistant and a physician and returns to the clinical assistant. The second sequence involves the addition of a nurse-practitioner to precede the physician in the sequence. Both sequences are more fully described in the Method of Procedure section of this study.

The OEO program of sponsoring such centers as the study site, ASCHC, is new. The place in society that it seeks to serve is unique--so unique in fact, that there is no satisfactory model to be followed. A climate for innovation is present at ASCHC as at others, which lacks tradition as a limiting factor. The absence of a frame of reference with which it can be compared, or from which it may borrow is somewhat a hampering factor, but it has meant that centers such as ASCHC have been permitted to develop individualized patient care formats which though similar to each other are not readily comparable. These similarities, not differences, were the reason ASCHC was selected for study.

The patient flow sequence, use of patient treatment rooms, and duties of personnel at the facility have, for the most part, been based upon administrative decisions which in turn have been the result of the experience of administrators aided by suggestions of staff personnel. No formal evaluation of the above mentioned factors was undertaken at ASCHC prior to the making of this study.

The urgency of the need which resulted in the establishment of ASCHC led to several changes in methods of recording information. These data were found to be inappropriate for study, except in broad general categories. Of these categories, data concerning patient arrival were kept consistently and could be used in this study. In addition, other data used were limited to data collected through a time study and to that produced by the Delphi method.

The criteria available for use in the evaluation of the various alternatives considered in this study are limited to the criterion of patient through-put volume. This criterion of the volume of patients through a health team medical unit effectively summarizes all sequence efficiency criteria such as personnel utilization, facility utilization, average cost per patient served, and the patient flow sequence effect. Since the primary purpose of the research is the evaluation of the effect upon patient volume of the addition of a nurse, this criterion is assumed to be acceptable for this research.

The respondents for the Delphi phase of this research were limited to the medical professional staff of ASCHC. The staff constitutes the panel of experts required by Delphi since they individually and collectively are highly trained personnel, posses a spectrum of experience, and have been closely allied with the development of ASCHC.

The Delphi estimates are limited to the assumption of a hypothetical stable team environment in terms of staff and patient and cannot be judged by the study of the current operating state which was performed in a changing team staff and patient environment. The Delphi technique is used as a means of refining opinion data and, as such, the data cannot be validated at the time of the study because of its nature as a step in pointing toward new and untried procedures. Only when systems have actually been tried through actual use can true validation be expected. This study, then, was limited to gaining an approximation of the true value of the interrelationships between the composition of health teams, available facilities, and a given average number of patients. The results were, in fact, limited to the conceptual models upon which they were based, i.e., estimated system inputs formed from the judgments of the experts providing the data.

1.7 Definition of Terms

1. Medical Unit: Each health team of an OEO center such as ASCHC is divided into two sections known as medical units. One medical unit serves adult patients exclusively and the other medical unit serves pediatric patients exclusively. Each medical unit consists of an appropriately trained physician (pediatrician or

internist), the appropriately trained ancillary personnel, and the stated number of examining rooms used exclusively by that unit.

2. Nurse-Practitioner: A registered nurse who has been specially trained in basic diagnostic internal or pediatric medicine with emphasis in screening methods and is thus qualified to precede the internist or pediatrician. (The nurse-practitioner is professionally and legally authorized to treat only certain types of patients and/or diseases. The extent of these authorized limitations depends upon the depth of the special diagnostic training, the amount of professional recognition, and the existing medical regulatory laws.)

3. Delphi Technique: A method for eliciting the consensus of a group of experts working individually, by the use of a series of responses refined by feedback.

4. Pediatric Patients: All persons 13 years of age and younger.

5. Adult Patients: All persons 14 years of age and older.

CHAPTER II

LITERATURE SURVEY

The components of the medical system within the health clinic of ASCHC are functionally similar to the medical systems of other health service institutions. Due to this fact and because of the limited attention given to health clinic systems in the literature, relevant studies concerning these were reviewed. The review was conducted primarily to determine the value of the systems approach to possible patient service at the ASCHC and to provide an aid to judging the research procedure most appropriate to the purpose of this research.

The first studies reported pertained to those made of the Nuffield Foundation in England during the early fifties. These were based largely on reflection and hindsight and little empirical data were used. These studies, as reported by Johnson and Rosenfeld[1], who also studied the health clinic environment, indicated that patient waiting time was affected by three controllable variables. These were: (a) the patient appointment system, (b) the patient arrival pattern, and (c) the staffing format of the clinic.

2.1 Systems Analysis and Simulation of Patient Flows

More recent approaches to the problems of health systems in general, and particularly of health clinics, have utilized systems analysis techniques with emphasis upon the simulation approach to systems analysis. Fetter and Thompson[2] reviewed several studies of patient waiting time versus doctor utilization in military health clinics. On the basis of their analysis of these studies, they hypothesized the influence of certain main factors upon the interrelationships between patient waiting time and physician utilization. A computer simulation model of the patient waiting time and physician utilization interrelationships was used to determine the effects upon the system of the main system parameters. These major parameters were found to be the patient arrival patterns and the staffing models of the clinic. The effect of each was highly significant.

Villegas[3] conducted experiments upon an outpatient clinic to determine the effect of various patient appointment patterns upon the utilization of the physicians. While his study supported the findings of earlier studies, the results are subject to question, since the service studied necessitated an overlapping of the experimental group and the control group of physicians and patients whenever excessive patient waiting or underutilization of physicians occurred in either group. This indicated the existence of an uncontrolled variable in the time required to serve a patient. The near infinite number of patient diseases to be treated and the wide range of patient types made control of this patient service time variable highly improbable.

William, Covert, and Steele[4] used Montes Carlo simulation techniques to study the relationship between patient appointment systems and the average waiting time of the patients in a teaching hospital environment. Their study did make recognition of patient examination time as a random variable. In addition, it extended beyond previous studies by considering a series of patient servers or examiners in addition to and in comparison with that of a single server. This study indicated that the systems approach and simulation in particular does produce satisfactory results when properly applied and when statistical control is maintained. (In this regard, it lent support to data provided in previous studies.) Other researchers who used computer simulation in health studies include Balintfy[5], who simulated the admissions and discharges in a hospital with a stochastic model; Goldman, Knappenberger, and Eller[6], who used computer simulation to test various bed allotment policies; and Robinson, Wing, and Davis[7], who used the computer to simulate hospital scheduling systems. Several studies have been done in the area of operating room scheduling using basically the same methodologies as were applied to the hospital scheduling problem. The works in this area by Bamoon and Wolfe[8] and by Goldman and Knappenberger[9 and 10] provide additional evidence of the value of statistical studies using simulation.

Computer simulation has been used in many other areas of the health field. Handyside and Morris[11] simulated emergency bed occupancy; Kilpatrick and Freund[12] used simulation effectively to investigate the tank oxygen inventory at a community general hospital.

The variety of purposes served and problems conducive to investigation by the simulation method is great. Leighton and Headley[13] used the method in a study to determine the length of hospital stay. Thompson and Fetter[14] have made numerous applications to hospital planning. An unusual application of simulation was reported by Cooley, Hall, and Packer[15]. Their study used simulation to provide estimates of the effectiveness of alternative medical support systems for the period immediately following a nuclear attack. Bonner[16] used the method to study emergency room service, and Kennedy[17] indicated that a simulation model of the health needs, demands, and resources for a community could be developed for use as a planning aid.

2.2 Delphi

Delphi is the name that has been applied to a technique for eliciting and refining the opinions of a group of people, usually a panel of experts. The Delphi technique replaces the traditional group method of direct discussion with a sequence of individual, autonomous responses to a series of questionnaires. The first questionnaire serves to provide the first respondent opinions and to acquaint each group member with the group's topics. The responses to the first questionnaire, as well as the responses to each subsequent questionnaire, are recorded and fed back to respondents as a matter of information. Measures of group consensus, the median and interquartile range of the responses of succeeding questionnaires are compiled and included in the feedback. These data concerning previous questionnaire responses thus become introductory to each subsequent questionnaire and serve to inform respondents of the then current status of group opinion.

The results obtained from Delphi applications, as Brown[18] points out, differ from the results obtained by traditional group discussion methods. The results of group discussion methods are always subject to the biasing influence of certain psychological factors associated with groups, "such as an unwillingness to abandon publicly expressed opinions, the conformity pressure of majority opinion, and the persuasive effect of dominant personalities."(18) The Delphi technique, as Helmer and Rescher[19] point out, "does not involve the use of discussion activity and is thus largely free of the influence of the psychological factors associated with communication through discussion."

The first application of the Delphi Technique was conducted in 1953 for the Department of Defense but was not reported until 1962 by Dalkey and Helmer[20]. The application concerned the strategic nuclear requirement for reducing the munition output of the United States by a set amount. The group or panel for the study consisted of seven experts. They were asked to respond to five questionnaires separated by weekly intervals. The first and third questionnaires were succeeded by interviews to determine the reasoning behind each participant's responses. The responses to the study questions converged from a ratio of 100 to 1 with the first questionnaire to 3 to 1 on the fifth questionnaire.

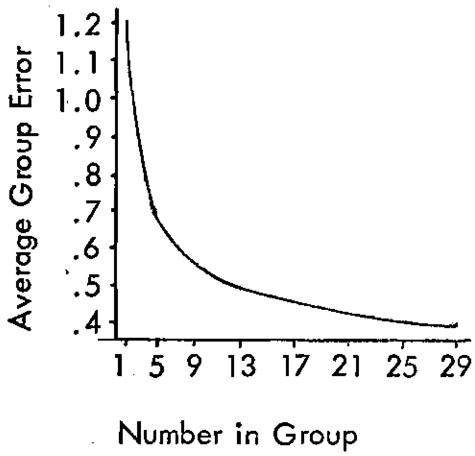
Dalkey in his descriptive paper on Delphi[21] points to the above study in indicating the value of Delphi in discovering the implicit models which are the basis for opinions. (He points out that the model for strategic nuclear bombing was later developed in more detail.)

In 1964 Brown and Helmer[22] conducted an experiment in Delphi at the Rand Corporation using 23 members of the Rand research staff as the group or panel of experts for the experiment. The objective of the study was to analyze the procedure of the Delphi technique. The twenty questions asked had numeric answers which could be found in the World Almanac. The subjects were asked to use no reference materials. The experiment was designed to test the hypothesis that initial divergent opinions would converge if feedback information was provided from the preceding interrogations. The measure of convergence was the interquartile range of the responses and the measure of the accuracy of each response was the absolute value of the logarithm of the group median response divided by the true answer. The results of the study indicated that the interquartile range shrunk in 95 per cent of the cases and that in 67-1/2 per cent of all cases the opinion pattern moved toward the true answer. (This was obtained by comparing the medians of the first and fourth rounds of questions with the true answer.) During the administration of the above experiment, the participants had been asked to rate their confidence in each response. Using the responses from those considering themselves the most expert, the study indicated that this group's responses moved in the true direction 77.5 per cent of the time and that their answers were within 25 per cent of the true answer in 70 per cent of the cases as opposed to 45 per cent for the respondents as a group. The study concluded by stating that "the use of self-appraised competence ratings in forming a consensus appeared to be a powerful tool for increasing the reliability of the group estimates." (22, p. 12)

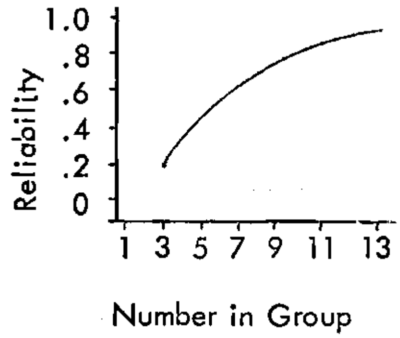
In 1964, Gordon and Helmer[23] applied the Delphi technique to long range forecasting. The study concerned the state of the world in the coming 25 to 50 years. The panel of experts consisted of six subpanels of 15 experts each, one subpanel for each area of interest (science, demography, automation, space, war prevention, and weapons systems). The results of the study were quite substantive both in terms of unexpected predictions for the future and also in terms of background for the Delphi technique.

One of the more interesting applications of Delphi was conducted by Robert M. Campbell[24] at the University of California. The application involved a controlled experiment using four randomly selected groups of graduate students. The groups were asked to develop forecasts for 16 economic indices for the first quarter of 1966. Two groups used the Delphi technique and two used the traditional business forecast techniques. The forecasts of the groups using the Delphi technique were more accurate than those made by the evaluational business forecast methods. The Delphi technique was used by a multi-disciplinary group studying the future directions of education in the United States[25]. The study indicated the Delphi could be useful in educational planning by providing a confluence of opinions. All of the above Delphi applications except for that by Brown and Helmer[(22)] have merely been Delphi applications in that they only indicated the applicability of Delphi but added very little to the operational knowledge of Delphi in terms of group size in relation to accuracy and reliability, and the value of self evaluation.

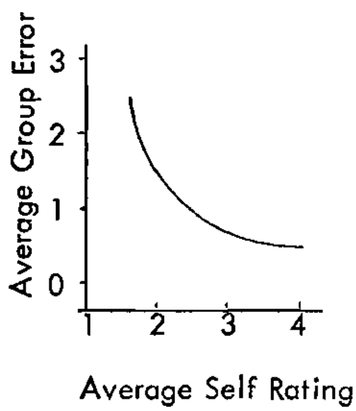
The most recent study into the actual operational relationships of accuracy, reliability, group size, and self rating was conducted by Norman Dalkey[26] for the U. S. Air Force and published in 1969. The study used groups ranging in size from one to 29. All of the questions used had known answers. The results of study indicated a definite relationship between group size and average group error as shown in Figure 2A as well as a definite relationship between mean error and group size as shown in Figure 2B. The implications drawn from the study concerning the value of self rating were that the individual self ratings when averaged would give a "group self-rating" which should be a measure of the accuracy of the group answer and the



A. Effect of Group Size



B. Reliability vs. Group Size



C. Group Self Rating

Figure 2. Delphi Operational Relationships

"solidarity" or "the degree of verification of an assertion in the opinion area." (26, p. 69). Figure 2C illustrates these implications.

The search of the literature concerning health centers per se proved to be of value despite the dearth of attention paid to it. It indicated clearly that the variables considered by ASCHC for study were to be found in the genesis of health service centers--indeed had been the basis for recording such data as were available. The lack of uniformity with which initial recordings were made, coupled with the stated importance of each, indicated the desirability of structured recordings concerning them from the beginning of subsequent studies.

The literature concerning health care centers showed a need for some means other than flashes of insight to provide direction and prognosis concerning direction. This in turn led to a search for a means which could provide this desired addition to insight. Such a means was found in the Delphi method which had been shown to be a valuable means of refining group insight into group opinion and to replacing the thinking and insight of the individual with that of the affected group. While still a relatively new tool of the student, its effectiveness had already been shown in a number of fields, including medicine. The literature concerning this method was carefully studied to provide guidance to the proposed study of ASCHC. The variables identified in the literature and chosen by the directors of ASCHC were in need of refinement and prognosis concerning them. The Delphi technique combined with a statistical models study showed promise of meeting this need.

CHAPTER III

COLLECTION AND ANALYSIS OF DATA

Data collection was carried out at ASCHC with the purpose of establishing parameter values for use in the simulation section of the study. Such data as were available from ASCHC which related to the study were limited to patient arrival times. Other data were collected by observing the performance of a health team. A work sampling study was used for the collection of data concerning the activity of physicians and the utilization of examining rooms and a time study was used to determine the service times associated with certain other activities. The procedures followed in collecting and preparation for use of these data are discussed later in this chapter.

Since comparison between an evolving "real world" patient flow sequence with that of a hypothetical alternate sequence was sought, an appropriate procedure for obtaining data concerning the hypothetical sequence was necessary. As indicated in the "Literature Survey," a modification of the Delphi technique gave promise of providing these data. This technique, as are the other data collection procedures, is covered in an appropriate section of this chapter.

3.1 Patient Arrival Pattern Determination

The arrival pattern of the ASCHC patients was studied to develop patient input characteristics for the computer simulation model. Data were developed for pediatric and adult appointment patients, and for walk-in patients. The data were used to simulate a patient input pattern which resembled the actual or existing pattern.

The procedure for developing appointment patient arrival data was as follows:

1. For the month of November, 1969, appointment schedules for the physicians were collected on all teams.

2. The following information was collected from the appointment schedules for every patient:

   A. Patient Number (unique to every patient)

   B. Time of Appointment

   C. Type of patient (child or adult)

3. These data were then compared using the ASCHC computer with the master patient file at the ASCHC to determine the differential between the time of a patient's appointment and the patient's arrival at the center.

4. The input in phase 2 for phase 3 consisted of data on 900 patients. The output from phase 3 consisted of data on only 280 patients. This very poor input to output ratio was a result of the condition of the ASCHC master file. It seems that the recording of a patient's arrival time for an appointment by a team receptionist did not occur regularly.

5. These 280 data points when divided into adult and pediatric patient classes further reduced the sample sizes to 118 for pediatrics and 162 for adults. Examination revealed that adults arrived an average of five minutes early and that children arrived an average of 4.6 minutes early.

6. The cumulative frequency distributions for both patient classes were determined and the distributions were used as in the simulation models. These distributions are shown in Table 1.

The procedure to determine the walk-in patient arrival pattern was:

1. From ASCHC patient files, 600 data points on the arrival times for walk-in patients were collected.
2. These data points were divided into hours and the rate of patient arrival as well as the pattern of arrival was determined for each hour.
3. The resultant data are shown in Table 2 and were used in the simulation section.

3.2 Observing Health Team Performance

The measuring of the performance of a clinical health team was made for two purposes. The first was to analyze the activities of a team pediatrician and internist to gain insight into ASCHC operations. The second purpose was the determination of the actual service times associated with the processing of patients through a medical unit. Some of these service times were used as constants in the simulation section; others were used in developing the simulation model.

At the time the observational studies were being designed, during the first week of November, 1969, the ASCHC had three health teams serving patients. These were teams A, B, and E, which had been open for 15, eight, and three months respectively. (Team designation is a function of location within the ASCHC building and not alphabetical order.) The fourth and final team, designated as team D, was at

Table 1. Appointment Patient Patterns of Arrival Relative to Time of the Appointment

Pediatric Patients			Adult Patients		
Cumulative Percentage of Patients	Time of Arrival (in Minutes) Relative to Time of Appointment	Coded for Computer	Cumulative Percentage of Patients	Time of Arrival (in Minutes) Relative to Time of Appointment	Coded for Computer
.000	50 (Early)	100	.000	51.0 (Early)	90
.040	36.3	237	.040	42.0	180
.065	29.7	313	.090	18.0	420
.119	20.0	400	.126	10.7	493
.185	12.0	480	.170	6.0	540
.260	6.1	539	.220	3.7	563
.350	3.0	570	.280	2.7	573
.460	1.8 (Early)	588	.480	1.2	588
.590	0.0 (On time)	600	.577	0.7 (Early)	593
.662	2.0 (Late)	620	.686	0.0 (On time)	600
.760	4.8	648	.760	1.5 (Late)	615
.852	6.0	680	.807	6.0	660
.910	11.8	718	.860	10.0	700
.960	18.0	780	.890	14.0	740
.988	24.0	840	.940	30.0	900
1.000	30.0 (Late)	900	1.000	80.0 (Late)	1400

Table 2. Walk-in Patient Arrival Patterns

A. Average Number of Walk-in Patients Arriving during Each Hour Interval

Hour Interval	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5
Average Number of Patients Arriving	.27	.875	1.15	1.05	1.25	1.10	.125	.105	.05

B. Cumulative Probability Distribution of Walk-in Patients Arriving during Each Quarter of Each Hour Interval

Hour Interval	9-10	10-11	11-12	12-1	1-2	Remainder not applicable due to small number of patients arriving.
1st Quarter Hour	.295	.290	.360	.312	.285	
2nd Quarter Hour	.715	.600	.445	.530	.525	
3rd Quarter Hour	.935	.820	.840	.765	.830	
4th Quarter Hour	1.000	1.000	1.000	1.000	1.000	

this time scheduled to begin operations in four to six weeks. The combination of these factors created the constraint that the collection of data be completed before the opening of the fourth team. This constraint was due to the fact that in the creation of a new team, the constituency of all teams is affected in that some personnel from the existing teams are transferred to the new team and replaced with new employees. In addition, the service area of ASCHC is then reallocated among the teams. The combination of personnel and service area changes results in problems in team effectiveness which, based upon the openings of the second and third teams, has required six to ten weeks for alleviation. A constraint of four to six weeks maximum study time dictated that the measurement studies be based on three weeks, since the fourth team could have been opened by the end of four weeks and the development of study instruments required one week.

The availability of only one full-time and one part-time observer coupled with the need to collect data which would be representative of the planned physician constituency of the ASCHC health teams further constrained the measurement studies. The planned physician staff for the health teams, which was one full-time internist and one full-time pediatrician, was present in only one team, team E, during the period of the measuring studies. Team A was staffed with a full-time pediatrician and a full-time general practitioner. Team B had a full-time internist and a part-time pediatrician. Team E, then, being the only team having the constituency planned in all teams, was used as the main data source and was observed by the full-time observer. The part-time observer was used to collect data from the pediatrician section of team A and the internist section of team B. The resulting data were 20 per cent representative of teams A and B. All data were pooled to reduce any possible data biasing effect that could have resulted from a study of team E only.

The inclusion of data from teams A and B was given credibility in that the ASCHC had indicated that they were in no way dissimilar to team E in any phase of service. The composition of teams A and B then was caused by a shortage of desired kinds of personnel. No team was at that time working to full capacity, and each was supported by consultants. For these reasons, it was felt that data collected concerning teams A and B were appropriate for inclusion in the study and indeed would add to the study's quantity.

3.2a Physician Activity Analysis

Selecting a method for analyzing the activities of a team's physicians was complicated by the fact that physicians were engaged in a multiplicity of unique activities, some of which occurred randomly and were non-repetitive, while others were routine. Still other activities occurred in the privacy of the examining room with the exclusion of any observer. All activities, however, could be divided into a finite number of definable categories. The technique selected to analyze the activities was work sampling, since work sampling can be used to collect data on categorized activities. Work sampling is also considered less disruptive than are other methods of work measurement.

The work sampling study was designed to be conducted over the three week period with observations to be taken randomly during three randomly selected days of each week. The first step in the design of the work sampling study was the determination of the maximum necessary or minimum acceptable sample size. The following formula based on the binomial sampling distribution was used in this determination (See[27], p. 299, for development of the formula.):

$$N = \frac{4\,OC^2(1-P)\,P}{I^2} \tag{1}$$

Where: N = Sample Size

P = Percentage of Time

I = Confidence Interval

OC = Representation of Confidence Coefficient C
(From the table of probabilities for normal distribution.)

Since the value of any activity's representative portion of time (P) was unknown at the time of the development of the study design, the sample size was based on a P = .5 since the sample size would then be the largest for this case, given C and I constant. A confidence coefficient C = .90 was selected and a maximum allowable confidence interval I = .10 was set. These values seemed adequate. Using these values of P = .5, I = .10, and for C = .90, OC = 1.645 (from the normal tables) the resultant sample size was found to be 270. Next, the procedure for collecting the minimum necessary 270 sample data points during the 15 remaining days available for study was determined. Since an observer's continuous presence during each of the 15 available study days could have influenced the study results, the number of data collection days was reduced from 15 to nine. The use of nine days allowed the observations to be taken during three randomly selected working days for each of the three weeks of the study, with a minimum of 30 observations per observation day.

In order to collect as many data points during each day as efficiently as possible, the interval method of work sampling was chosen rather than the completely randomized observation time method. The time interval between observations was selected as ten minutes. The observation interval could have been greater than ten minutes, but this would have reduced the sample size upon which the results were based. Time study had been rejected as the data collection technique because of the random occurrence nature of some of the activities. In order to eliminate the biasing effect caused by having the observation interval, a known multiple of the minutes in an hour, the time of the initial observation for both the morning and afternoon observation periods was randomized. The use of ten minutes as the observation interval simplified randomization since the time for the initial morning observation was simply the team opening time plus one random digit. The initial afternoon observation time was simply the time a physician returned from lunch plus the same random digit. This method was used to compensate for the variation in lunch time used by the physician. This design resulted in from 30 to 45 observations being taken per day.

For purposes of the work sampling study the activities of the physicians were grouped into the following categories:

1. Examining Patients: All patient related activities which were performed only within an examining room were included under this category. Some examples of activities included within this category are: (a) taking additional facts about a patient's medical history, (b) examining a patient, (c) prescribing or administering treatment or drugs based upon examination findings, and (d) recording examination findings and the resultant

action taken.

2. Consultation: Consultation of medical literature as well as the consultation between physicians which were made either in person or by use of the telephone was included in this category.

3. Charting: This category consists only of the recording by a physician of the results of studies which had not been completed at the time of a patient's departure. Some examples are: (a) EKGs, (b) lab tests, and (c) X-rays.

4. Waiting for examination preparation: Physician idleness due to waiting for a patient to be prepared for examination.

5. System problems: System problems were administrative problems that affected the physician and his treatment of patients. These problems were associated mainly with medical records, nursing, and the administration of the ASCHC. The physicians took time from treatment of patients to deal with these problems.

6. Idle: No patients to be seen and the physician waiting in his office and not involved in specific activity.

7. Break: Personal break time excluding lunch.

8. Miscellaneous: All activities not otherwise described.

Although the primary aim of the work sampling study was an analysis of the physician's activities, additional data were collected pertaining to the team's clinical assistants and examining rooms. The activities of the clinical assistants were studied because they were part of the current team concept and their inclusion was anticipated in future teams. The examining rooms were observed to determine the percentage of time the rooms were actually used. These data were used for comparisons which are described later. The activities for both clinical assistants and examining rooms are listed in Tables 3 and 4.

The findings on the physicians' activities which are summarized in Table 5 indicated that they were devoting 70 to 80 per cent of their time to patient and personal activities, thus indicating that only a 20 to 30 per cent increase in the patient load would be possible under current arrangements. The implications were that either the physicians would reduce the average patient examination time or that certain patients would be screened from the physicians if the ASCHC was to serve much more than the 5,000 patients it was serving at the time of the study. This indicated a need for research to determine how to more effectively process patients through a health team. Differences in time use of internists as compared with that of pediatric personnel indicated the possible need for the addition of more adult units.

The results of the observations of the clinical assistants are summarized in Table 3. The tabulation of these activities provided some rather interesting data when compared with that of the physicians. Whereas the mean non-patient function of the physician was found to be less than 30 per cent, the total means of the non-patient functions of the clinical assistants was found to be also less than 30 per cent. In neither case were normal break time nor lunch time considered. A need for experimentation seems to be indicated to determine the preferred number of clinical assistants needed or to more clearly define the duties of this position. Such experimentation, however, was considered to be not within the scope of this study.

Table 3. Clinical Assistant Activity Analysis

No. Observations - 426

Activities	Percent Occurrence
1. Preparing patient for examination	23.12
2. Waiting with patients after (1.) for the physician	11.50
3. Assisting physician or present during examinations	24.10
4. Clearing patients out of a room after physician leaves	4.94
5. Idle due to no patients	8.22
6. Break - personal	8.00
7. Miscellaneous non-patient related activities	14.82
8. Cleaning examining rooms	1.80
9. Idle - no known reason	3.50
Patient related activities 1, 3, 4	52.16
Non-patient, non-personal activities 5, 7, 8, 9	29.32

(This indicates that patient load could be increased by almost 30 per cent by eliminating or reducing the time devoted to the activities listed in this category.)

Table 4. Room Use Analysis

No. Observations - 625

Room Uses	Percent Occurrence	
	Pediatric Rooms	Adult Rooms
1. Vacant - not occupied by patients	45.2	31.4
2. Occupied only by a patient	12.9	28.0
3. Occupied by a patient and a clinical assistant	17.9	18.0
4. Used for examination	20.5	21.4
5. Miscellaneous non-patient uses	3.5	1.2

Table 5. Physician Activity Analysis

No. Observations - 328

Confidence Coefficient $(1 - \alpha) = 0.90$

Activities	Pediatrician		Internist	
	Percent Occurrence	Confidence Interval	Percent Occurrence	Confidence Interval
1. Examining Patients	39.6	39.6 ± .043	52.4	52.4 ± .045
2. Consultation	13.7	13.7 ± .031	14.0	14.0 ± .030
3. Charting	6.8	6.8 ± .023	8.0	8.0 ± .050
4. Waiting for Examination Preparation	6.1	6.1 ± .023	3.6	3.6 ± .017
5. System Problems	5.2	5.2 ± .020	5.2	5.2 ± .020
6. Idle	17.1	17.1 ± .032	3.6	3.6 ± .017
7. Break	8.8	8.8 ± .025	4.0	4.0 ± .018
8. Miscellaneous	2.7	2.7 ± .015	6.2	6.2 ± .022

The confidence coefficient (C) defines the probability (P) that the estimate $\bar{Z}$ of the parameter Z falls within a range defined by two numbers Z1 and Z2. Where the range Z1 and Z2 is the confidence interval. Thus it is expected that at C = .90, or 90% of the time, the range Z1 to Z2 of $\bar{Z}$ contains the parameter Z.

The results of the examining room use analysis are summarized in Table 4. One of the unexpected findings was that the examining rooms were vacant more than 45 per cent of the time. The patient time in examining rooms was spent more in waiting and in being prepared than with the physician. Almost as much time was spent waiting as with the physician. In view of the fact that teams were not then considered as working to capacity, this finding seems to imply a need to determine a means of utilizing the team service areas more effectively.

While the findings in this section of the study have indicated a need for a more thorough consideration of facility utilization and of the position of clinical assistant, these data were not collected for these purposes. The observations were clearly made for other purposes and noted implications were a by-product.

3.2b Service Time Observation

Data on the service times of the activities listed was collected and is shown in Table 6. The activities listed in this table are associated with the processing of patients and for purposes of this study were considered independent of the selected variables of the investigation (sequence, facilities, medical unit) and of the measurable (patient volume). The service time values for these activities, hence, were considered constants and were developed from the real world data collected.

The design of a method for collecting the necessary service time data was limited by the design of the work sampling study. The work sampling had been designed to be conducted on three randomly selected days during each of three weeks. The service time data collection was then designed to be conducted concurrently with the work sampling study. Since the work sampling design had been based on

Table 6. Service Times

1. Patient Preparation Time

A. Excluding Patient Medical History. No. Data Points = 84.

(1) Time Period in Minutes (Computer Coded)	1 (10)	2.2 (22)	3.5 (35)	4.7 (47)	6.1 (61)
(2) Cumulative Percentage of Occurrence within Each Time Period	17	62	84	94	100

B. Including Patient Medical History. No. Data Points = 84.

(1) Time Period in Minutes	3	6	9	12	15
(2) Cumulative Percentage of Occurrence within Each Time Period	17	62	84	94	100

		Coded for Computer Useage	
		Mean	Spread *
2. Duration of Physicians' Lunch Break			
No. Data Points = 20	Mean = 67.0 min. Range = 55 min. to 80 min.	670	100
3. Time Required to Enter a Patient into the System			
No. Data Points = 27	Mean = 1.2 min. Range = Negligible	12	0
4. Time Required to Make an Appointment			
No. Data Points = 23	Mean = 2.2 min.	22	0
5. Time Required to Clear a Patient Out of an Examining Room after the Physician Leaves			
No. Data Points = 33	Mean = 1.0 min. Range = 0 to 1.8 min.	10	8

*Uniform distribution between mean + spread and mean - spread.

sample size, this design basis was not appropriate for the service time collection design. As a result, the design of the service time collection was based upon developing the maximum possible number of data during the time available. The method selected was to note and record the beginning and ending times of an activity; by so doing, many activities could be and were timed simultaneously. Because few activities were continuously observed, the work sampling observations could be taken with a minimum effect upon the timings being made. The service time data, however, when tabulated and examined were found to be characterized by small sample sizes. The small sample sizes, however, did not represent a serious problem since the values obtained from these data were used only as constants in the conceptual models.

The results of the service time determination are listed by activity in Table 6, and the sample sizes of all these activities were less than 40. In addition, since these four activities were not directly involved in the servicing of patients as interpreted by the simulation phase of the study, no distribution or spread was considered necessary. Activity 1 in Table 6, however, was directly involved with the servicing of patients as interpreted by the simulation phase of the study. Also, the sample size for each section of Activity 1 in Table 6 was more than twice that for any other activity in Table 6. A distribution based on the sample was used to represent each division of Activity 1 in Table 6. All of the activities listed in Table 6 were used with the values shown in the simulation phase of the study.

Data concerning the time physicians spent with patients were also collected as part of the service time study. The data which are listed in Table 7 were collected simply to have a base to compare with the results of the Delphi phase of the study.

Table 7. Physician Service Times

Adult Physician

Time Period in Minutes	0-5	6-10	11-15	16-20	21-25	26-30
Percentage Occurrence	9.1	16.4	32.9	13.4	14.8	13.4

Child Physician

Time Period in Minutes	0-5	6-10	11-15	16-20	21-25	26-30
Percentage Occurrence	10.4	29.7	37.3	14.0	8.1	3.5

3.3a Delphi Application

In the problem statement a sparsity of data related to health center formats of the type sponsored by OEO was brought out as a factor which complicated the evaluation of alternative methods of delivering health care in such centers. It was also pointed out that the data such as were available were poorly collected and organized due to the infancy of the OEO concept of neighborhood health centers.

The professional staffs of such centers, as was also mentioned, collectively represented many years of training and experience in the field of health care delivery which, when properly organized could be used to aid in the evaluation of various methods of health care delivery by centers of the type sponsored by OEO.

The procedure used for applying the Delphi technique was based primarily on applications of the procedure used by the Rand Corporation of California which had done much of the empirical research involving this technique. Modifications were found necessary because of three basic differences: (1) The respondents in the Rand Corporation were involved directly as a part of their regular duties whereas the professionals in the ASCHC did so as volunteers and on their own time. (2) The number of persons available as respondents to the Rand studies was quite numerous as compared with the 30 professionals available at ASCHC. (3) Line administrative control of Rand respondents assured total reply to each presentation of the Delphi instruments within one week while responses at ASCHC necessarily were dependent upon the free time and willingness of the respondents.

Because of the above reasons, the following changes were made in the technique: (1) Three replications of the Delphi questionnaire were used at ASCHC as opposed to the four used in the Rand studies. (2) Time for replies was extended beyond one week to such time as it became evident that maximum probable response had been obtained. (3) The data provided by those respondents who replied to all replications of the Delphi at ASCHC were used in conjunction with data provided by persons who responded to fewer than all replications; whereas Rand studies could and did include 100 per cent responses to all replications.

Similarities between the Delphi technique as used by the Rand Corporation and that used at ASCHC were as follows: (1) In the first round each respondent was requested to estimate an answer to each question and to rate his level of confidence in the correctness of his answer on a four point scale. (2) In the second round of questioning, each question was accompanied by the group response median and interquartile response range of the first round. Each respondent was requested to consider these statistics in responding to the question and if the response was not within the interquartile range to state a brief reason explaining this. (3) In the third round, statistics similar to those provided in round two were included plus a summary of reasons for violation of interquartile ranges in this round. Again the respondents were requested to provide brief comment concerning answers in which their opinion continued outside the interquartile range. Step three, as performed at ASCHC and steps three and four as used by the Rand Corporation followed the pattern established in round two. (4) Both used the median of a question's responses as the single number representing the collective opinion of the responding group and the interquartile in an ordered ranking of a question's responses as the measure of central tendency of the respondent group's opinion. These statistics are intuitively appealing in being independent of scale with the net effect of providing a realistic measure of the opinions of the respondent group to the questions on the questionnaire.

The questionnaire used in the ASCHC application of the Delphi (see Appendix II) contains questions designed to collect needed information and to be as explanatory as possible without indicating an answer. It was reviewed by both the Director of Medicine and the Director of Nursing of ASCHC for their critique prior to the first round presentation. Ambiguities and problem areas were corrected, the members of the professional staff were contacted, the purpose of the study was explained, and the first round questionnaire was distributed.

All distributions of the Delphi questionnaires were made at regular weekly staff meetings. At the first of these the Delphi technique was explained and the respondents were told of the type of responses desired for each type of question. Progress reports by the researcher accompanied the distribution of second and third round questionnaires. These reports were not accompanied by discussion by respondents nor any information designed to affect the opinions of respondents.

The respondent group was composed of ten physicians and 20 registered nurses. These persons formed the group of experts necessary to use the Delphi technique. Of these, 27 replied to at least one iteration of the questionnaire. Two iterations were received from seven of the respondents, while four replied to all three. This did not represent a general loss of interest, however, because 15 replied to the first round, 13 to the second round, and 12 to the third and final round. The total number of persons responding to questionnaires was high, as were the number of responses to each round. This pattern of responses seemed to bear out the assumption that time for replying to so complex a problem was difficult to work into the busy schedules of these professionals.

Further evidence to support the assumption concerning time, as stated above, was demonstrated by the fact that first round responses were in some cases turned in three weeks late, second round responses as late as four weeks and third round responses as late as six weeks. There was also a sharp drop in explanations for exceeding interquartile range of questions between rounds two and three and in rating of level of confidence between rounds one and two and two and three.

The Delphi procedure was necessarily modified after the second questionnaire since a third and fourth round as originally planned were not applicable. The modification decided upon was to limit the application of Delphi to three rounds. Only the medians and interquartile ranges from the second questionnaire were used as the feedback information provided for the respondents' consideration in the third round. The distribution of the third round questionnaire was accompanied by a personal discussion with each participant.

The effect of not being able to use the Rand type Delphi application procedure cannot be calculated. The results of the Delphi procedure used, however, did produce convergence in 66 (75 per cent) out of 88 questions. Convergence occurred when the absolute value of the interquartile range for the preceding round was greater than that for the immediate round. The overall convergence performance is illustrated in Table 8.

Another method of measuring convergence was the Maximum Interquartile Limit (MIL). The MIL is the greatest absolute difference between the median and

Table 8. Delphi Convergence Performance

Eighty-eight Questions per Questionnaire

	Number Occurrence	Percent Occurrence
Overall Convergence (Spread Round 1 Spread Round 3)	66	75
Convergence Round 1 to Round 2	48	55
Convergence Round 2 to Round 3	53	61
Convergence Round 1 to Round 2 to Round 3	29	33
Absolute Convergence (No Spread at Round 3)	18	21

either interquartile limit expressed as a percentage of the median. This statistic had an average value for all 88 questions in the first round of 115.3 per cent. In the second round this was reduced to 78 per cent and was further reduced to 52 per cent in the third round. The overall convergence then as measured by this statistic was an average of 110 per cent between rounds one and three. The calculation of the final found MIL produces some rather interesting findings which are summarized in Table 9.

While a convergence of opinion occurred on the majority of questions, on some questions a firm lack of agreement was demonstrated by a constant interquartile spread from one round to another. Table 10 illustrates the occurrences of this firm lack of agreement. Another interesting result was that the interquartile range was the same in rounds one and three, seven (eight per cent) times. The medians of the questions generally changed from one round to another. The median of only one question was constant during all three rounds. The median was constant from rounds one and two for four questions. From round two to round three, 11 questions had a constant median.

3.3b Delphi Application Results and Conclusions

The very nature of the Delphi portion of this study has been that of obtaining the best judgment of competent, involved personnel to determine the appropriateness of a current patient flow pattern and of a different patient flow pattern and changes in facilities as they may affect patient flow. The overlying purpose has been to provide data upon which more effective and economical operation of the health center could be obtained by innovations in patient flow patterns.

Table 9. Final Maximum Interquartile Limit

1.	In 26 (30%) of the questions	MIL $\leq$ 25% Median
2.	In 52 (60%) of the questions	MIL $\leq$ 50% Median
3.	In 72 (82%) of the questions	MIL $\leq$ 100% Median
4.	In 8 (9%) of the questions	MIL $>$ 100% Median
5.	In 8 (9%) of the questions	MIL was undefined, Median = 0

The above indicate the ranges of final variability of the responses to the Delphi questions as related to the questions' means by the MIL.

Table 10. Occurrences of Constant Interquartile Ranges

	Number Occurrence	Percent Occurrence
Constant Spread Round 1 and Round 2	9	11
Constant Spread Round 2 and Round 3	12	14
Constant Spread Round 1, Round 2, and Round 3	4	5

The specific findings of the study have been shown in tabular form in Tables 11, 12, and 13. These specific findings indicate the following generalizations: (1) The respondents believed that the alternate patient flow patterns would make it possible for more patients to be served. (2) They demonstrated a decided belief in the value of one additional treatment room for each physician. (The number of respondents expressing a need for the additional treatment room was much higher than the number who desired no change in facilities as they were from the number indicating the advisability of adding more than one.) (3) The fact that rooms were 40 per cent vacant at the time of the study indicated a possible bias. (4) The median level of confidence in opinions expressed was high (2.3 on a scale in which the numeral 1 indicated the highest level of confidence and the numeral 4 expressed the least confidence). (5) The sequence one average physician service times per patient were 15.2 minutes for the pediatrician and 16.53 minutes for the internist. When sequence two was considered, the average service times were 14.9 for the pediatrician and 15.4 for the internist. (6) The respondents' estimates of current time spent with patients was somewhat greater than the actual time as determined by observation. The observation that some patients required a comparatively long period of time provided evidence of possible bias.

The fact that respondent physicians indicated (Table 14) that the second flow sequence would make it possible for more persons to be served is evidence of a probable willingness on the part of this group to delegate certain treatment tasks to specially trained nurses. (It would appear probable that such tasks should be identified either categorically or specifically. The knowledge and skill necessary to

Table 11. Pediatrician Service Time Data Developed by Delphi

	Service Times						Average Service Time
Interval Used in Delphi	0-5	6-10	11-15	16-20	21-25	26-30	
Sequence One							
Appointment Patients							
Discrete Percentage	3.14	15.8	42.2	21.0	12.6	5.26	15.0
Cumulative Percentage (Used in Computer)	3.14	18.9	61.1	82.1	94.7	100.00	
Walk-in Patients							
Discrete Percentage	0.0	14.0	37.4	37.4	9.34	1.86	15.4
Cumulative Percentage	0.0	14.0	51.4	88.8	98.1	100.00	
Sequence Two							
Appointment Patients							
Discrete Percentage	0.0	18.2	27.6	36.2	13.6	4.4	15.9
Cumulative Percentage	0.0	18.2	45.8	82.0	95.6	100.0	
Walk-in Patients							
Discrete Percentage	4.28	21.33	38.52	25.62	8.54	1.71	13.9
Cumulative Percentage	4.28	25.6	64.1	89.8	98.3	100.00	
Observed Data							
(From ~~Appendix I~~ Table 7)							
Discrete Percentage	10.4	29.7	37.3	14.0	8.1	3.5	12.8

Table 12. Internist Service Time Data Developed by Delphi

Interval Used in Delphi	Service Times 0-5	6-10	11-15	16-20	21-25	26-30	Average Service Time
Sequence One							
Appointment Patients							
Discrete Percentage	4.8	11.5	38.4	24.2	14.4	6.7	16.98
Cumulative Percentage	4.8	16.3	54.7	78.9	93.3	100.0	
Walk-in Patients							
Discrete Percentage	0.0	12.6	34.7	36.9	10.5	5.3	16.08
Cumulative Percentage	0.0	12.6	47.3	84.2	94.7	100.0	
Sequence Two							
Appointment Patients							
Discrete Percentage	2.8	14.3	33.3	28.6	14.3	6.7	16.03
Cumulative Percentage	2.8	17.1	50.4	79.0	93.3	100.0	
Walk-in Patients							
Discrete Percentage	0.0	19.0	43.0	28.6	4.7	4.7	14.77
Cumulative Percentage	0.0	19.0	62.0	91.6	96.3	96.3	
Observed Data							
(From Table 7)							
Discrete Percentage	9.1	16.4	32.9	13.4	14.8	13.4	16.02

Table 13. Nurse-Practitioner Service Time Data Developed by Delphi

Interval Used in Delphi	Service Times 0-5	6-10	11-15	16-20	21-25	26-30	Average Service Time
Appointment Patients							
Pediatric							15.00
Discrete Percentage	0.0	10.0	40.0	50.0			
Cumulative Percentage	0.0	10.0	50.0	100.0			
Adult							13.78
Discrete Percentage	5.5	16.7	44.5	33.3			
Cumulative Percentage	5.5	22.2	66.7	100.0			
Walk-in Patients							
Pediatric							11.02
Discrete Percentage	0.0	17.7	47.7	35.6			
Cumulative Percentage	0.0	17.7	65.4	100.0			
Adult							13.52
Discrete Percentage	2.6	15.4	51.0	31.0			
Cumulative Percentage	2.6	18.0	69.0	100.0			

Nurse Screening Time

Adult	Children
100% in 15 min.	25% in 10 min. 75% in 15 min.

Table 14. Delphi Data Implications

1. Effects of increasing the number of examining rooms in sequence one:

   A. 20% More pediatric patients would be seen with three instead of two examining rooms.

   B. 15% More adult patients would be seen with three instead of two examining rooms.

2. Sequence two effects:

   A. 20% of All pediatric patients will see only the nurse.

   B. 25% of All adult patients will see only the nurse.

   C. The pediatric patient volume may increase by 20%.

   D. The adult patient volume may increase by 25%.

   E. Four examining rooms per medical unit may be required.

accomplish this would in turn become a part of the job description and training of such nursing personnel.)

The choice of one additional patient treatment room per physician was questioned by the researcher. The rationale expressed by the respondent group was that this addition would reduce the probability of lost time on the part of a physician while a patient was being prepared. It would also provide privacy for a patient to dress or to be instructed by the clinical assistant after having been seen by the physician. The rooms would be used in a rotating system with preparation followed by seeing the physician or nurse practitioner or both and that in turn followed by dressing and instruction. For the most part, the three room provision was believed to reduce physician-patient time.

The median level of confidence which the respondents expressed in making choices is quite important when considered in the framework of the study as a whole. It would appear probable that the error in judgment as shown by comparing respondents' estimates of current patient time with actual patient time (as determined by observation) is one of quality rather than kind. No plan can be measured fully until it has been put into effect and then only by a means specifically designed to measure it. The study seeks to compare opinion with opinion. The confidence level of opinions obtained in this study adds much to their meaning.

The estimated time comparison with reality is available only for the current situation (sequence one). It is safe to assume that such a comparison may show direction of bias error. The fact that actual mean patient time was significantly less than estimated mean patient time does suggest that the physician believes that he spends more time with each patient than is actually spent. It probably has nothing to do with his estimate that certain changes in patient flow and/or patient treatment rooms will tend to increase his effectiveness.

Based upon the concept that the use of the Delphi technique tends to refine and "accurize" data, the differences found in estimated patient time with the physician becomes more than statistically important. The addition of an extra patient treatment room for each team physician would decrease the physician-patient time by 15 per cent, thus increasing the number of patients which could be effectively seen in a day by 18 per cent. A change of patient flow to a sequence including a nurse-practitioner with no increase in patient treatment rooms would result in a decrease in physician-patient time of 15 per cent and an increase of 15 per cent in the number of patients who could be seen. The change to the second patient flow sequence which includes the nurse-practitioner plus the addition of one additional patient treatment room per physician would reduce patient time from the current flow pattern facility situation by five per cent and would increase the number of patients per physician by 22 per cent. (None of the above percentages includes the number or percentage of the total patient load who would receive treatment from the nurse-practitioner only. However, it is evident that these would be in line with increases in physician effectiveness. Collection of data appropriate to this function could be inferred only since the position does not now exist--indeed, there are no personnel specifically trained to provide a data source.) However, when the estimated percentage of the total patient load which could be added because of the increased percentage in physician availability, it would appear that a markedly greater number of patients could be served by the proposed change in patient-flow sequence using additional stations (one per unit physician) than is currently the case.

3.4 Service System Characteristics of a Medical Unit of a Health Team

The components of the patient flow sequences simulated in this research are patients, physicians or nurses and physicians, and numbers of examination rooms. This is essentially a processing problem where the number of patients processed during any particular time interval depends upon the sequence, the time required to process through each service point in that sequence, and the number of examining rooms available wherein patient service may be provided. Complicating the problem is the fact that the rate of patient input does not occur at predetermined times; the time required for patient service at each service point is not constant; the service personnel (physician or nurse and physician) are not continuously available but are subject to interruptions and breaks for personal needs; and the specific route through each sequence is not predictable for any patient.

Patient input is for the most part random. Appointment patients may be scheduled, but their arrival at a health team varies around the scheduled appointment time and cannot be predicted with accuracy. Appointment patients arriving reasonably on time are given priority in processing through the health team medical unit. The arrival of walk-in patients is largely related to the time of day. Very few arrive during the early or late hours but tend to arrive randomly in the late morning and early afternoon period. No patients are allowed to enter the health team system if by so doing working hours will be extended past regular team closing hours. These patterns are tabulated in Tables 2 A and B.

The time associated with or required to serve a patient (prepare, screen, or examine) depends upon the patient. Simple medical problems usually require less service time than do more complex cases. The complexity of each patient's medical problem is not predictable and hence the service times seem random. The service times are not identical for appointment patients and for walk-in patients. No specific preparation is made for treating walk-in patients whereas special preparation may or may not be necessary for appointment patients. The appointment's problem usually has been pre-diagnosed, while the walk-in's problem is to be diagnosed. The relative time thus devoted to each type of patient can be expected to be affected by this factor. The amount of preparation time required for nurse screening is less than that required for preceding direct physician examination. Also, the time required for physician examination is affected by any preceding preparation or screening. Tables 6, 7, 11, 12, and 13 illustrate the various service time distributions, some of which were developed by the Delphi application at ASCHC while others are taken directly from observations of ASCHC health team operations.

The physicians and nurses who are involved in the servicing of patients are not continuously available to team service because of interruptions such as consultation and administrative duties. Since personal breaks are not scheduled but are permitted, continuous presence of the total medical unit cannot be expected. Nurses, usually, are more available than physicians since personal breaks are the primary cause of nurse unavailability, whereas physicians are unavailable due to consultation, charting, and other reasons in addition to personal breaks. Unavailabilities resulting from personal breaks are comparable for both physician and nurse.

The above interruptions to both physician and nurse availability are not scheduled but occur randomly. Tables 3 and 5 show the percentage occurrence and the time duration ranges of the interruptions which occurred at ASCHC.

The flow of patients is interrupted to allow the servers (physician or nurse and physician) a lunch period. Patient flow into the examining rooms ceases at noon and the servers leave for lunch immediately upon completion of any service then ongoing. The duration of the lunch break is similar for both nurse and physician but is not a constant time interval. Table 6 shows the lunch break durations observed at ASCHC.

Patients entering the medical unit service system are routed from a reception area to the waiting area. Patients are directed from the waiting area to available examining rooms (availability of examining rooms is determined by the number provided and the rate of processing patients through the rooms). Each patient then occupies an examining room during the entire processing through his treatment sequence. (The patient flow sequence is in fact the sequence in which servers enter the occupied examining rooms rather than a sequence of moves by the patients.) The patients are first prepared for screening or examination depending upon the particular sequence. They then wait to flow through the remainder of the servers of their particular sequence. Finally, patients are processed out of the team area and the examining room is returned to available status to await the input of another patient.

3.5 The Computer Model

A model was developed for each of the two patient flow sequences described in the method of procedure. The flow diagrams illustrated in Figure 1 were used as the framework from which the models were constructed. To the basic framework outlined in Figure 1 were added sections which approximated the characteristics of the medical unit service systems characteristics described in section 3.4. The UNIVAC 1108 General Purpose Systems Simulator (GPSS II) language was used for the models since it permitted simultaneous model design and computer programming. The two models are described in detail and the assembly inputs or program listings are presented in Appendix III.

Validation of the models of the two sequences was not possible. Both models are based upon conceptual frameworks which were developed from the intuitive judgments of members of the professional staff of ASCHC. In addition, many of the service time distributions used in the models were developed under the assumption of a hypothetical stable team operating environment--one which does not now exist but which is anticipated in the future. The sequence involving the nurse exists only in conceptual form. The sequence using only the physician, though quite similar to the sequence in use at ASCHC, was constructed only to represent the sequence concept and not the then current performance of the sequence at ASCHC. In addition, the nature of the experiment was to evaluate the respective sequence concepts and not to compare the performance of the concept of sequence two with the performance of sequence one at a single moment in time.

3.6 The Simulation Experimental Design

The computer models were used in a (2 x 3) fixed factor effects factorial experimental design to evaluate the two patient flow sequence levels at the three examining room levels for each of the two types of medical units. Ten replications per factorial cell (sequence--examining room provision combination) were used to increase the reliability of the results of the experiment. Each replication represented the number of patients which the models processed during three days of simulated operation. Every replication represented a separate computer run (60 being required for each of the two medical unit factorial layouts) and a different random number seed for each of the required runs was used to facilitate complete randomization. The mathematical model for this experiment and design is $X_{ijk} = u + R_i + S_j + RS_{ij} + E_{m(ij)}$ where X_{ijk} represents the measured variable, u, a common effect in all replications, and R_i represents the number of rooms effect where i = 1, 2, 3. S_j symbolizes the sequence type effect where j = 1, 2. $E_{m(ij)}$ represents the random error in the experiment where m = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. RS_{ij} stands for the interaction between the two main factors R and S, which is an additional effect due to the combined influence of the two main factors. Both R_i and S_j are fixed factors.

The 120 computer simulation runs required for this experiment were made on the UNIVAC 1108 located at the Rich Electronic Computer Center of Georgia Institute of Technology during late February and early March, 1970. The results in numbers of patients processed during three days of simulated operation are given in Table 15 in the factorial design used.

3.7 Analysis of Experimental Results

The experiment and the mathematical model suggest a two-way fixed factor analysis of variance (ANOVA). One ANOVA is made concerning the adult medical

Table 15. Data Generated by Computer Simulation

	Adult			Pediatric		
	2 Rooms S1R2	3 Rooms S1R3	4 Rooms S1R4	2 Rooms S1R2	3 Rooms S1R3	4 Rooms S1R4
S	X_i	X_i	X_i	X_i	X_i	X_i
E	88	92	92	92	98	91
	89	90	94	93	87	94
Q O	83	83	90	99	97	99
	90	96	92	92	92	91
U N	80	89	90	85	94	98
	92	93	92	95	92	100
E E	80	84	87	91	93	96
	81	83	91	85	91	93
N	86	89	97	97	95	101
	92	91	93	92	94	95
C						
	$\overline{X} = 86.2$	$\overline{X} = 89.0$	$\overline{X} = 92.0$	$\overline{X} = 92.1$	$\overline{X} = 93.3$	$\overline{X} = 95.8$
E	s.e. = 1.48	s.e. = .43	s.e. = .84	s.e. = 1.42	s.e. = 1.00	s.e. = 1.14

	S2R2	S2R3	S2R4	S2R2	S2R3	S2R4
S	X_i	X_i	X_i	X_i	X_i	X_i
E	82	102	103	83	100	98
	79	91	100	84	94	93
Q T	83	95	96	80	100	94
	76	94	102	78	94	107
U W	81	105	102	84	95	104
	83	96	90	78	97	99
E O	82	95	99	94	91	105
	79	98	93	75	97	108
N	80	103	97	80	99	116
	81	97	104	82	96	99
C						
	$\overline{X} = 80.6$	$\overline{X} = 97.6$	$\overline{X} = 98.6$	$\overline{X} = 81.8$	$\overline{X} = 96.3$	$\overline{X} = 102.3$
E	s.e. = .69	s.e. = 1.4	s.e. = 1.45	s.e. = 1.62	s.e. = .92	s.e. = 2.23

Note: 1. Each number represents the number of patients processed by a medical unit during three days of operation. Ten replications per cell were performed.

2. X_i = One Replication

3. $\overline{X}$ = Cell average

4. s.e. = Cell standard error

unit and another ANOVA is made concerning the pediatric medical unit. These ANOVAs appear in Table 16.

The null hypotheses of no room effect (R), no sequence effect (S), and no (R x S) interaction effect were tested in the ANOVAs with a significance level of $\alpha = .05$.

In each ANOVA the mean square of each of the two main effects (R and S) and that of the R x S interaction were tested against the error mean square. The test statistic used in all cases was the F statistic (Hicks[31] Table D) with the appropriate degrees of freedom. The ANOVA procedure used was that presented in Hicks Fundamental Concepts in the Design of Experiments[31], Chapter 6.

The ANOVA concerning the adult medical unit data indicated that all null hypotheses could be rejected at the $\alpha = .05$ level. The number of rooms effect, sequence type effect, and room x sequence interaction effect were indicated significant. The ANOVA concerning the pediatric medical unit data indicated that only the null hypothesis of no sequence effect could not be rejected at the $\alpha = .05$ level. The number of rooms effect and room x sequence interaction effect were indicated significant while sequence type effect was not.

In both ANOVAs the interaction team was significant. This significance means that a level change in one of the two factors has produced a different change in the response variable at one level of the other factor than at the other levels of this other factor. (See Figure 3.) The indicated significances of the main factor effects are then subject to question since these significances are affected by the interaction effect in addition to the factor effect.

Table 16. ANOVA for Room-Sequence Effect upon Patient Volume:

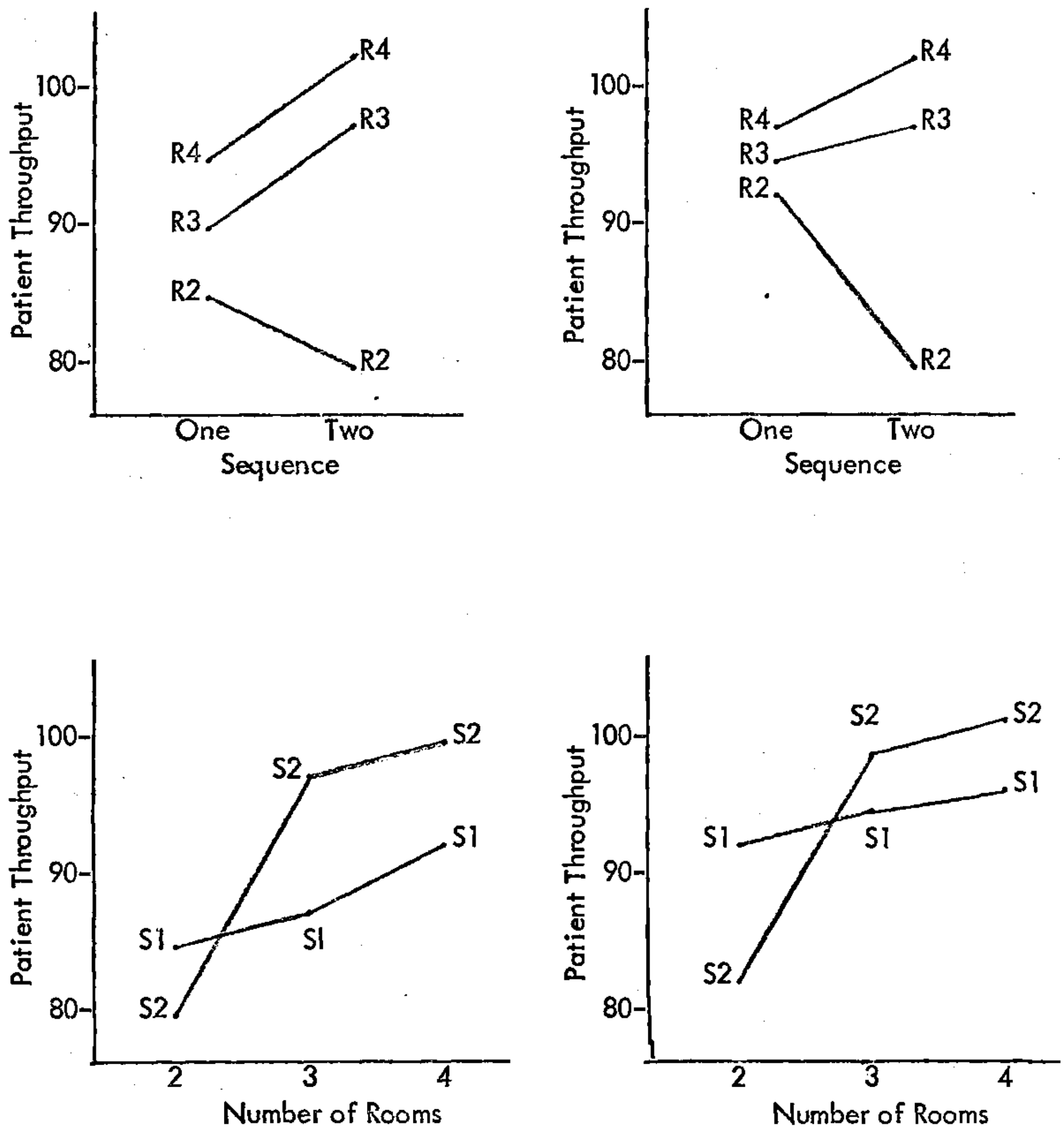
2 x 3 with 10 Replications per Cell for Both the Adult and Pediatric Medical Units

Adult

Source of Variation	Degrees Freedom	Sum of Squares	Mean Square	Significant at $\alpha = .05$
No. of Rooms	2	1620.3	810.15	Yes
Sequence Type	1	163.4	163.4	Yes
Room X Sequence Interaction	2	588.8	294.4	Yes
Error	54	853.7	15.81	
Totals	59	3226.2		

Pediatric

Source of Variation	Degrees Freedom	Sum of Squares	Mean Square	Significant at $\alpha = .05$
No. of Rooms	2	1507.30	758.65	Yes
Sequence Type	1	1.07	1.07	No
Room X Sequence Interaction	2	785.63	392.81	Yes
Error	54	1154.4	21.38	
Totals	59	3448.40		



Interaction is indicated graphically by nonparallel or intersecting lines.

Figure 3. RXS Interaction

This interaction when interpreted indicated that the relationships between numbers of rooms and sequence used was not independent. The relationship between the two main effects and their interaction was then examined graphically using the cell means from Table 15 to produce Figure 3. A brief examination of the graphs on these figures indicates that the interaction (indicated by nonparallel or intersecting lines) occurs between the two room and the three room levels at the two sequence levels. Very little interaction seems to occur between the three room and the four room levels at the two sequence levels.

Since one of the main purposes of the experiment was to determine what factor levels caused what effects, the cell means (each R_iS_j combination) associated with each unit type were investigated. This investigation was made even though the significant interaction was present.

The problem of comparing these cell means is part of a general class of problems known as multiple comparisons. The fact that these comparisons were being made after the data had been examined limited the procedures which were available to those which would not affect the significance level α. There are many methods for making multiple comparisons which preserve the α level such as Newman-Keul's procedure, Scheffe's method, Tuckey's method, and many others. Because of its wide application Duncan's Multiple Range Test was selected as the procedure to be used. This is used as illustrated by Hicks[31], page 31.

Duncan's Multiple Range Test involves what is known as a least significant range or LSR which is a product of the standard error ($S\bar{x}.j$) of the mean for each cell and a significant studentized range at the α level desired, using N_2 = degrees of freedom for error mean square and p = 2, 3,--,K, K = the number of cells. The procedure operates as follows: If the absolute value of the difference between any two cell means exceeds the LSR, the effects of the two means are judged to be significantly different; if the absolute value of the difference between any two means does not exceed the LSR, no such conclusion is reached. A detailed derivation of Duncan's Multiple Range Test may be found in his original article in "Biometrics."[33]

Following the procedure, all cell means associated with each unit type were arranged in numerical order from high to low as the first step of Duncan's Multiple Range Test procedure. In each unit type the order of cell means was observed to be the same, specifically: S2R4, S2R3, S1R4, S1R3, S1R2, S2R2 where S1, 2 = sequence one or two and where R4, 3, 2 = four, three, or two rooms. The cell means associated with each sequence were tested to gain insight into the room effect given a particular sequence. The cell means associated with each room level were tested to gain insight into the sequence effect given a particular number of rooms. Duncan's Multiple Range Tests appear in Table 17 for the adult and in Table 18 for the pediatric.

At this point it may seem reasonable that a more direct procedure would have been to have at first tested for significant differences between all possible pairs or groups of means. One two-sample t test would be required to test the significance of each possible pair. The six cell means associated with data representing each medical unit type can be divided into seven possible pairs or groups of means, thus requiring seven two-sample t tests. This procedure was not used, however, because the overall results would not be statistically valid. According to Miller and Freund (29), "these tests would not be independent and it would be virtually impossible to

Table 17. Duncan's Multiple Range Procedure and Test - Adult

1. Ranking of Cell Means

K = 6 Cells	6	5	4	3	2	1
Cell Means	98.6	97.6	92.0	89.0	86.2	80.6
Cell Designation	S2R4	S2R3	S1R4	S1R3	S1R2	S2R2

2. Standard Error of Mean:

$$S\bar{x}.j = \sqrt{\frac{\text{Error Mean Square from ANOVA}}{\text{No. Observations in } \bar{x}.j \text{ or Cell}}} = \sqrt{15.81/10} = 1.26$$

3. Least Significant Ranges (LSR)*:

P =	2	3	4	5	6
LSR =	3.56	3.75	3.88	3.95	4.03

4. Test of Cell Means:

Hypothesis means are equal. Reject if difference in means exceeds LSR.

Cells Tested	Difference of Means	LSR	Significant
S2R4 vs S2R2	18.6	4.03	Yes
S2R4 vs S2R3	1.0	3.56	No
S2R3 vs S2R2	17.6	3.56	Yes
S1R4 vs S1R2	5.8	3.88	Yes
S1R4 vs S1R3	3.0	3.88	No
S1R3 vs S1R2	2.0	3.95	No
S2R4 vs S1R4	6.6	3.56	Yes
S2R3 vs S1R3	8.6	3.75	Yes
S2R2 vs S1R2	5.6	4.03	Yes
S2R3 vs S1R4	5.6	3.56	Yes

5. A one dimensional scale illustrates the various significances:

S2R4 S2R3 S1R4 S1R3 S1R2 S2R2

Means underscored by the same line are not significantly different. Means not underscored are significantly different.

*The LSR are products of the standard error = 1.26 and the significant ranges for α = .05 and n2 = 54 (d.f. of mean square error) from Table E of Hicks[31].

Table 18. Duncan's Multiple Range Procedure and Test - Pediatric

1. Ranking of Cell Means:

K = 6 Cells	6	5	4	3	2	1
Cell Means	102.3	96.3	95.8	93.3	92.1	81.8
Cell Designation	S2R4	S2R3	S1R4	S1R3	S1R2	S2R2

2. Standard Error of Means:

$$S_{\bar{x}.j} = \sqrt{\frac{\text{Error Mean Square from ANOVA}}{\text{No. Observations in } \bar{x}.j \text{ or Cell}}} = \sqrt{21.38/10} = 1.462$$

3. Least Significant Ranges (LSR)*:

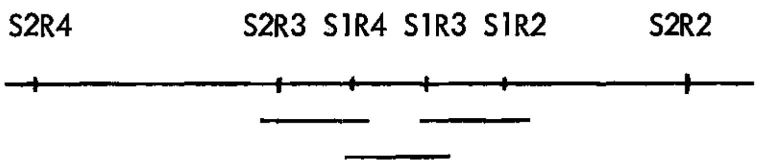
P =	2	3	4	5	6
LSR =	4.14	4.36	4.50	4.59	4.68

4. Test of Cell Means:

Hypothesis means are equal. Reject if difference in means exceeds LSR.

Cells Tested	Difference of Means	LSR	Significant
S2R4 vs S2R2	20.50	4.68	Yes
S2R4 vs S2R3	6.00	4.14	Yes
S2R3 vs S2R2	14.50	4.14	Yes
S1R4 vs S1R2	3.7	4.36	No
S1R4 vs S1R3	2.5	4.36	No
S1R3 vs S1R2	1.2	4.50	No
S2R4 vs S1R4	6.5	4.14	Yes
S2R3 vs S1R3	3.0	4.36	Yes
S2R2 vs S1R2	10.3	4.59	Yes
S2R3 vs S1R4	.5	4.14	No

5. A one dimensional scale illustrates the various significances:



Means underscored by the same line are not significantly different. Means not underscored are significantly different.

*The LSR are products of the standard error = 1.462 and the significant studentized ranges for α = .05 and n2 = 54 (d.f. of mean square error) from Table E of Hicks[31].

assign an overall level of significance to this procedure." For reader interest only analysis by the procedure of multiple t tests has been presented in Appendix IV.

3.8 Findings of Analysis

The findings resulting from the analysis of the simulation data concerning the addition of the nurse (sequence effect) and varying the number of examining rooms per medical unit indicated the following:

1. Concerning the addition of the nurse or sequence effect:

   A. The ANOVA's indicated that the addition of the nurse was not generally significant in the pediatric unit and was generally significant in the adult unit. These were only indications due to the significance of the interaction effect.

   B. The comparisons made using Duncan's Multiple Range Test indicated that in both units the patient throughput was reduced significantly at the two room level by the nurse addition and was significantly increased at the three and four room levels. This apparently indicates that two rooms are insufficient for both the nurse and the physician to carry out their sequence two duties without mutual interference. The interference probably acts to reduce patient throughput. The increases observed at the three and four room levels indicated that interference did not act to reduce the patient throughput and that the nurse addition did appear to increase the throughput.

2. Concerning varying the number of examining rooms per medical unit effect upon patient throughput:

   A. The ANOVA's indicated that varying the number of examining rooms per medical unit was generally significant for both medical unit types. These are indications only due to significant interaction.

   B. The comparisons made using Duncan's Multiple Range Test indicated the following: In both units and for both sequences the effect of increasing from two to four rooms appeared significant; the effect of increasing from two to three rooms appeared significant only for sequence two in both units; the effect of increasing from three to four rooms appeared significant only for pediatric sequence two. These indicate that more than two rooms per unit are generally significant in increasing patient throughput.

From the above statements the following inferences can be drawn: (1) that under the current ASCHC health team medical unit area layout (two rooms) the effect of adding a nurse practitioner to the medical units would be to reduce the patient volume by two to five per cent, (2) that if a medical unit is provided with more than two rooms (three or four) the addition of the nurse will increase the patient volume by two to ten per cent, (3) that increasing the number of rooms from two to three is effective in increasing patient volume only if the nurse is also added to the medical unit with the extent of the increase being about five per cent, and (4) that the addition of a fourth room will increase the patient volume only in the pediatric unit and then only if the nurse is added.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The objective of this research was to evaluate the effects upon the volume of patients through an OEO center health team medical unit adding a specially trained nurse to the sequence of unit personnel serving patients and of varying the number of examination rooms per medical unit. The evaluation was accomplished in Chapter III.

From the results presented in Chapter III, the following effects were noted: 1) When only two examining rooms per unit are available, the addition of the nurse acts to reduce the patient volume through the unit. 2) When three examining rooms per unit are available, the addition of the nurse acts to increase the patient volume. 3) The availability of a fourth examining room did not seem to be of value statistically in increasing patient volume. From these resultant effects the following conclusions may be drawn:

1. The addition of a nurse is effective in increasing the volume of patients through a medical unit only if a sufficient number of examining rooms per unit are made available.
2. Three examining rooms per unit are sufficient for the addition of the nurse to be effective in increasing patient volume.
3. The addition of the nurse is more effective in increasing the patient volume in the adult medical unit than in the pediatric medical unit.

The results of the evaluation section of this study have indicated that it is possible to evaluate conceptual, innovative proposals for delivering health care at centers such as ASCHC on quantitative bases in order to ascertain the relative effects upon the numbers of persons served of the various proposals. Since the evaluation procedure was based upon conceptual models and the evaluative criterion used was numbers of persons served, the results are intended to be used only to supplement the judgments of the planners, designers, and directors of health care delivery centers.

The results of this study have shown that it is possible to evaluate innovative proposals for delivering health care which may only be conceptualized by the incorporation of the experience and intuitive evaluation powers of professionals who deliver health care into a systems analysis and simulation of the proposals.

4.2 Recommendations

On the basis of data obtained in this study, several recommendations are made for further study for both verification of the findings themselves for effective use of them. These are as follows:

1. Institute the proposed sequence two at the current center and accompany it with a time study to determine the desirability of the change in flow pattern.
2. On the basis of data thus obtained, if favorable, alter one team area and test the actual effectiveness of additional examining rooms. Then, if favorable, move into a new facility which would provide the desired increase in the number of examining rooms. The time study should be

continued and changes made as needed for further improvement.

3. Develop a flexible job description for the nurse practitioner which could be used in selection, training, or both.

4. Revise the job description of the nurse practitioner on a regular basis to keep it in line with any new skills or duties which may in time become a part of this position.

5. Develop a system of record keeping which would lend itself readily to computer analysis. Such factors as disease category, selected data from medical history, recovery time, age, sex, marital status, source of income, educational level, date of treatment are but a few of those which may affect physician time with patient. Other factors as they are identified as having effect on the economy of operation should be coded, recorded and studied.

6. As sufficient data are collected, as suggested in 5 above, a study should be made to determine the patient-physician time at which effectiveness is reduced by either being too little or too much. Such a study would probably be affected by disease category and other patient data.

7. Regularly review the patient-physician ratios within all units of all health teams serving the center. The data concerning adult patients differ numerically from those concerning pediatric patients sufficiently to indicate a probable need to place major emphasis on increasing adult services as the center reaches closer to its expected patient volume.

Physicians are indeed in short supply. This research has indicated a belief by medical professionals that the patient-physician volume can be increased within the regular work day. It has further demonstrated that this can probably be accomplished through the inclusion of specially trained nurse practitioners within team unit sequences and by the availability of an additional patient treatment room to each unit. Statistical evidence concerning these is sufficient to justify experimentation including them. Only by so doing can they be validated. They have nonetheless pointed out a direction which offers promise, and a technique for providing such estimates has been demonstrated herein.

APPENDIX I

STUDY SITE

A1.1 Setting

To provide a clear understanding of the environmental and situational factors which have bearing on the problem studied, certain information concerning the study site, the neighborhood served, and its comparison with the larger community is provided. The time, the place, the people, and the setting in general provide the variables which have led to the making of this study. They also compose the setting necessary to and affecting the conclusions drawn, either as a part of this research, or which may develop as a result of it. The ASCHC is the third to be established of 41 neighborhood comprehensive health centers sponsored nationally by the OEO. Its establishment was accomplished through the joint efforts of the Fulton County Medical Society, Emory University Medical College, the local office of OEO (Economic Opportunity Atlanta), and the residents of the intended target neighborhood, the Price neighborhood of Atlanta (see Figure 4). The center was initiated in June, 1968, with a funding of a $2,200,000 OEO grant. Operation of the facility is a cooperative effort of the founding agencies.

A1.2 Service Area Characteristics

The Price neighborhood of Atlanta was selected as the target area for ASCHC by the Economic Opportunity Atlanta (see Figure 4). According to data tabulated

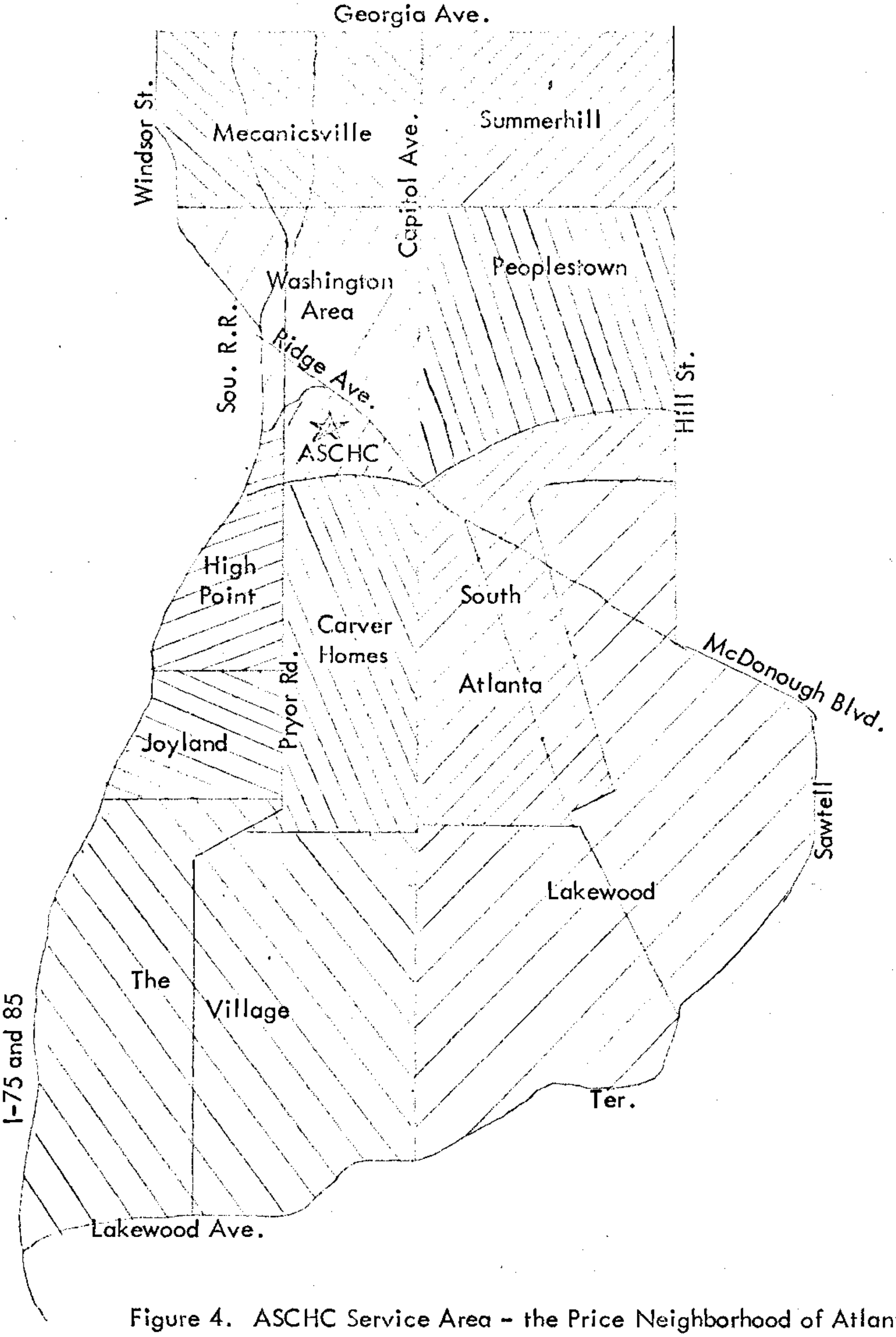


Figure 4. ASCHC Service Area – the Price Neighborhood of Atlanta

by the center, it has a population density of approximately three times that of Atlanta as a whole, containing 1.4 per cent of the city's area and 4.4 per cent of its population; yet it contains 10.2 per cent of Atlanta's deteriorated housing and 6.8 per cent of its dilapidated housing. It has, during the past twenty years, changed from a middle class section of town into a slum.

The health level of the neighborhood's inhabitants is much lower than for Atlanta as a whole. The occurrence of premature birth is 80 per cent higher, the infant mortality rate is 48 per cent higher, the overall death rate is 48 per cent higher, tuberculosis new case rate is 56 per cent higher and the incident of all communicable diseases is 120 per cent higher. Thus the health needs of the ASCHC target neighborhood are decidedly greater than those found in the usual neighborhood within the city. Since the city itself has a high rate of health care need, the neighborhood degree of need is far greater than the above percentages would indicate.

The ASCHC neighborhood has a total population of approximately 28,500, of which some 16,000 were currently eligible for medical services offered by the ASCHC by virtue of being classified as at or below the poverty level by OEO. (The current poverty definition for a single person is an annual income of no more than \$1,635; for a married couple, \$2,200; for a married couple with two or more children, \$3,335. Where marriage is not a factor, income maximums are determined by the number of persons in a household.) The population of the neighborhood is 75 per cent non-white, 54 per cent female, and 50.2 per cent under 20 years of age.

A1.3 Facility and Staff

Due to the recency of its establishment, the staff of ASCHC was not yet staffed as originally intended. The facility, a converted factory, was not originally designed to be a health facility, but has been remodeled to serve health teams and certain specialists. Four health teams each with two medical units were a part of the original plan. Of these, only one was staffed as designed and had operated as a team for more than six months. One team was relatively new, one used part-time personnel, and one was not organized as planned. Each health team was to have been staffed by a full-time internist and a full-time pediatrician with such auxiliary personnel as the patient flow sequence dictated. Under the current pattern, a team administrative nurse was included. Under the proposed plan, two patient serving nurses would be provided for each team. Non-professional needy persons from the service neighborhood were employed as clinical assistants. They alone are in ample supply. The eight physicians plus their auxiliary personnel formed the clinical staff.

The health teams have the services of specialists available to them, either to serve as consultants or to refer patients from the team area to other areas of the ASCHC where they will provide specialized treatment. These include consultants in obstetrics, gynecology, psychiatry, opthamology, physical medicine, neurology, dermatology, ENT, surgery, orthopedic surgery, dentistry, and radiology. All medical services are supported by a team of social workers. The use of these consultants is determined by the patient's need as judged by the team physician. The total medical staff of ASCHC is now 20 physicians full and part time. This is in marked contrast to the one physician who served the Price neighborhood prior to the establishment of ASCHC.

The physical design of ASCHC was dictated by OEO guidelines which have since been changed. These guidelines stated that no completely new structures could be built to house comprehensive health centers. Because of this ruling and the "run down" condition of the neighborhood, an old bed factory was remodeled to serve as the center's building. It was the largest obtainable building within the neighborhood. It did not provide the desired physical layout, but was remodeled to serve. Both needs and specifications were compromised to make this possible, but this study did not deal with the problems caused by the center's current physical layout. The problems caused by the physical layout are sufficient in scope to require a number of specialized studies directed toward their solution.

The guidelines of OEO implied that an ideal arrangement for the clinical service area of the health teams would be two examining rooms for the team pediatrician or pediatric medical unit and two examining rooms for the team's internist or adult medical unit. Since this arrangement was used in other OEO centers and since the ASCHC's planning board agreed that the center could operate with these, such was the basis on which a team's service was partitioned. For a while this was a satisfactory arrangement. Rooms were not used to capacity. As the patient load had grown to serve 7,000 persons by December, 1969, the lack of additional space was causing a bottleneck. As the patient load increases toward the expected 16,000, the lack of space may become critical.

A1.4 Organization for Service

Although much of the organization of centers such as ASCHC were the direct result of OEO guidelines, some latitude was permitted, indeed considered advisable, for the program administrator and his staff. The current solution method in use by the ASCHC is to meet problems as each arises. The newness of the team approach plus the escalation of the numbers of persons receiving medical service has lead its administrator to express an interest in innovative ways of improving the center's ability to deliver volume comprehensive health care. The problems faced seemed too complex to be solved by trial and error alone and a need for prognostic evaluation of plans was felt. The current innovative concept under consideration, that of an addition of a nurse or nurse-practitioner to the sequence of personnel serving a patient, was proposed for predictive consideration. This concept was described previously. Intuitive judgments were sought in this study in an effort to evaluate this change before it would be put into practice.

Non-professional team personnel, referred to elsewhere as clinical assistants, were employed in keeping with an OEO guideline that as many of the residents of the center's service neighborhood be employed in as many employee positions as practically possible. The planning board of ASCHC theorized correctly that, with training, such personnel could carry out functions normally assigned to certain medical assistants in private medical practice. With further training it is probable that these personnel will assume an even more important share of service than is now the case in either the current or the proposed patient flow patterns, particularly as they seek professional status as practical nurses, registered nurses, or medical technicians.

ASCHC is still in the growth stage of developing its patient clientele. Eligibility determination based solely on financial need does not assume a clientele nor does the proposed size of the facility guarantee a complete staff. Both staff and clientele have increased since the opening in June, 1968, to the extent that all four teams are now formed and are serving approximately 7,000 patients. The administrator believes that all teams will be approximately equally loaded in terms of average daily patient volume by June, 1971. After this, depending upon funding and the efficiency with which the teams function, they expect the average patient load to increase at a more or less regular rate. A quarterly rate of increase is estimated at no less than five per cent nor more than 50 per cent. This is a wide range indeed, but is justified by the unknown effect of the three controlling variables: staff efficiency, patient acceptance of the facility, and population fluctuations. It is expected that all eligible persons will be served by the facility within the next three to five years. If this should occur, and if the three variables above have the expected effect, some 16,000 patients will be served by the teams. It is interesting to note that the full time physician to patient ratio will then be 1:2000, which is twice the current national average. It is highly desirable that the center may be able to serve this patient to physician ratio through better physician utilization and not by an increase in the average work day of the physician.

APPENDIX II

EXAMPLE DELPHI QUESTIONNAIRE

In this questionnaire you will be asked to make certain estimates using your best judgment as an experienced medical professional. These estimates will involve both physician and nurse examination times and the influence upon these examination times of certain center policies. In making your estimates you are asked to assume the existence of an experienced, full time clinical staff which has operated long enough to function as a team. Also, you should assume that all departments of the center are functioning properly. Lastly, you are asked to assume that the functions and duties performed by the non-physician clinical staff members may be to the maximum extent of their training and within the limits of present and future medical regulatory laws.

You are asked to rate your responses by writing a 1, 2, 3, or 4, indicating your confidence in the accuracy of each response with 1 being for very confident. Your confidence measure should reflect the hypothesis that if all responses were ranked according to their distance from a true answer and then grouped into four equal sets by distance from this true answer your response would be contained within the 1st, 2nd, 3rd, or 4th set of this ranking.

The questionnaire is divided into sequences which have been designated as one and two. Sequence refers to the order in which clinical personnel come into contact with a patient. Sequence one consists of a clinical assistant followed by an examining physician. The physician is followed by a clinical assistant. Sequence two consists of a clinical assistant followed by a nurse-practitioner who is followed by a physician as warranted by the patient's complaint. A clinical assistant then follows either.

Sequence One

In this sequence the order of personnel coming into contact with a patient is as follows: 1) clinical assistant, 2) examining physician, 3) clinical assistant. The roles have been defined as follows:

1) clinical assistant - prepare the patient for examination.
2) examining physician - examine this patient and take such action as the examination results dictate.
3) clinical assistant - prepare the patient to leave the team area and interpret the examination and resultant instructions for the patient.

You are asked to consider the following points in making your responses:

1) Both the pediatric and adult sections of the health team are provided with two examining rooms each. This is the same as the current arrangement.
2) The clinical portion of the health team consisting of the adult and pediatric sections is provided with four clinical assistants. This is also the same as the current arrangement.
3) The examination time which you will be asked to estimate will be composed of time requirements for the actual examination, the prescribing of any corrective measures dictated by the examination, and the charting of both.

The actual response requested from you is an estimate of the percentage of patients from each of the categories listed below whose examination by the physician will have been completed within each of the listed time intervals. Definition of terms:

U - Upper quartile limit

M - Median

L - Lower quartile limit

Percent of patient examinations completed within each applicable time interval with the total equaling 100%.

		Time Intervals with Time in Minutes					
		a 1-5	b 6-10	c 11-15	d 16-20	e 21-25	f 26+
Patients Having an Appointment							
1.	Pediatric Patients Answer Rating ____ 1, 2, 3, or 4	U-5 M-2 L-0	U-25 M-10 L-10	U-50 M-40 L-25	U-45 M-22 L-10	U-25 M-10 L-5	U-10 M-3 L-0
2.	Adult Patients Answer Rating ____ 1, 2, 3, or 4	U-5 M-2 L-0	U-15 M-7 L-5	U-40 M-32 L-30	U-20 M-15 L-10	U-50 M-10 L-5	U-75 M-10 L-8
Walk-in Patients Seen							
3.	Pediatric Patients Answer Rating ____ 1, 2, 3, or 4	U-4 M-0 L-0	U-30 M-25 L-5	U-40 M-19 L-10	U-40 M-25 L-20	U-30 M-25 L-10	U-10 M-5 L-1
4.	Adult Patients Answer Rating ____ 1, 2, 3, or 4	U-2 M-0 L-0	U-15 M-5 L-0	U-25 M-17 L-10	U-40 M-20 L-20	U-20 M-17 L-15	U-5 M-5 L-3

You are now asked to assume that the clinical section is equipped with three examination rooms for the pediatric section and three for the adult section. Estimate the change, if any, in the average examination time as a result of having three examination rooms instead of two examination rooms.

Patients Having an Appointment

5. U-25 M-10 L-10 — Pediatric Patients
_________% Change in the Average Examination Time
Answer Rating _________ 1, 2, 3, or 4

6. U-25 M-10 L-5 — Adult Patients
_________% Change in the Average examination Time
Answer Rating _________ 1, 2, 3, or 4

Walk-in Patients Seen

7. U-15 M-10 L-10 — Pediatric Patients
_________% Change in the Average Examination Time
Answer Rating _________ 1, 2, 3, or 4

8. U-25 M-15 L-10 — Adult Patients
_________% Change in the Average Examination Time
Answer Rating _________ 1, 2, 3, or 4

You are also requested to estimate the percentage increase, if any, in the average daily number of patients each section could see if it were provided with three examination rooms instead of the current two examination rooms.

9. U-20 M-20 L-10 — Pediatric Patients
_________% Increase in the Average Daily Number of Patients Served
Answer Rating _________ 1, 2, 3, or 4

10. U-30 M-20 L-10 — Adult Patients
_________% Increase in the Average Daily Number of Patients Served
Answer Rating _________ 1, 2, 3, or 4

Would four examination rooms instead of two or three examination rooms per section increase the average number of patients seen by each section?

11.	Pediatric	Yes_____	Amount_____%	U-X M-25 L-X	No_____
12.	Adult	Yes_____	Amount_____%	U-X M-20 L-X	No_____

Sequence Two

This sequence involves the addition of a nurse-practitioner to the sequence outlined in "Sequence One" between the clinical assistant who prepares the patient and the physician who examines the patient. The nurse-practitioner will extend the preparatory examination of the clinical assistant into a more detailed examination, thus affecting the amount of examination required of the physician. In addition, the nurse-practitioner will screen some patients from the physician.

The nurse-practitioner is a registered nurse with special training in certain areas such as well baby care or normal pre-natal care including basic diagnostic training. You are to assume that the nature of the nurse-practitioner's training has made him/her more proficient in the performance of certain functions but not better qualified than a physician.

In considering the scope of these duties and functions assume that the center's physicians, as a group, have delegated the responsibility for the performance of these duties and functions to the nurse-practitioners based upon their knowledge of the training and capabilities of the nurse-practitioner.

Sequence two then consists of a clinical assistant followed by a nurse-practitioner who is followed by an examining physician, if warranted by the nature of the patient's complaint. A clinical assistant follows the nurse or the physician. The roles have been defined as follows:

1) clinical assistant - Prepares the patient for examination.

2) nurse-practitioner - Extends the preparatory examination of the clinical assistant. The remainder of the definition of the nurse-practitioner's role is left to you and will be reflected in your answers.

3) examining physician - Examines patients and takes action as dictated by the examinations.

4) clinical assistant - Prepares patient to leave the team area and interprets the examination and resultant instructions for the patient.

You are to consider the effects of the addition of a nurse-practitioner to the clinical health team.

First, you are asked to estimate the percentage of each section's patients, if any, that will be seen only by the nurse-practitioner and not by the physician. A patient may be screened from the physician by the nurse-practitioner as a result of the nature of the patient's complaint or the routine nature of his visit.

13.	U-25 M-10 L-15	Pediatric Patients	_____% seen only by nurse-practitioner	Answer Rating _____ 1, 2, 3, or 4
14.	U-33 M-20 L-15	Adult Patients	_____% seen only by nurse-practitioner	Answer Rating _____ 1, 2, 3, or 4

You are asked to estimate the time a nurse-practitioner will spend examining a patient in order to reach a decision whether or not to screen that patient from the physician.

15. U-15 M-15 L-8 — Pediatric Patients — ________ time to screen or not — Answer Rating ________ 1, 2, 3, or 4

16. U-15 M-15 L-10 — Adult Patients — ________ time to screen or not — Answer Rating ________ 1, 2, 3, or 4

Of those patients seen by the physician, please estimate the percentage of patients whose examination by the physician will have been completed within each of the presented time intervals. You are reminded that the nurse-practitioner has preceded the examining physician. Remember, that examination consists of the actual examination, the resultant corrective measures, and the charting of both.

	Percent of patient examinations completed within each applicable time interval with the total equaling 100%.					
	Time Intervals with Time in Minutes					
	a 1-5	b 6-10	c 11-15	d 16-20	e 21-25	f 26+
Patients Having an Appointment						
17. Pediatric Patients Answer Rating ________ 1, 2, 3, or 4	U-8 M-0 L-0	U-29 M-10 L-0	U-35 M-30 L-20	U-40 M-20 L-15	U-20 M-15 L-10	U-5 M-5 L-2
18. Adult Patients Answer Rating ________ 1, 2, 3, or 4	U-5 M-0 L-0	U-20 M-15 L-10	U-25 M-15 L-1	U-40 M-30 L-25	U-40 M-20 L-10	U-10 M-5 L-10

Percent of patient examinations completed within each applicable time interval with the total equaling 100%.

Time Intervals with Time in Minutes

Walk-in Patients Seen

		a 1-5	b 6-10	c 11-15	d 16-20	e 21-25	f 26+
19.	Pediatric Patients						
	Answer Rating	U-5	U-20	U-35	U-30	U-10	U-10
		M-0	M-20	M-30	M-20	M-7	M-5
	1, 2, 3, or 4	L-0	L-0	L-20	L-10	L-5	L-1
20.	Adult Patients						
	Answer Rating	U-5	U-20	U-50	U-25	U-30	U-10
		M-0	M-10	M-50	M-20	M-10	M-5
	1, 2, 3, or 4	L-0	L-0	L-40	L-15	L-5	L-0

Of those patients seen only by the nurse-practitioner, you are asked to extimate the percentage of patients whose examination by the nurse-practitioner will have been completed within each of the presented time intervals. Again, you are reminded that examination consists of the actual examination, the necessary corrective measures, and the charting of both.

Patients Having an Appointment

		a 1-5	b 6-10	c 11-15	d 16-20	e 21-25	f 26+
21.	Pediatric Patients						
	Answer Rating	U-3	U-10	U-60	U-30	U-10	U-5
		M-0	M-5	M-50	M-25	M-0	M-2
	1, 2, 3, or 4	L-0	L-0	L-40	L-20	L-0	L-0
22.	Adult Patients						
	Answer Rating	U-10	U-20	U-50	U-50	U-5	U-5
		M-10	M-10	M-30	M-10	M-0	M-0
	1, 2, 3, or 4	L-0	L-5	L-30	L-10	L-0	L-0

Percent of patient examinations completed within each applicable time interval with the total equaling 100%.

		Time Intervals with Time in Minutes					
		a 1-5	b 6-10	c 11-15	d 16-20	e 21-25	f 26+
Walk-in Patients Seen							
23.	Pediatric Patients Answer Rating ______ 1, 2, 3, or 4	U-5 M-3 L-0	U-40 M-30 L-20	U-40 M-30 L-25	U-35 M-30 L-20	U-5 M-3 L-0	U-5 M-0 L-0
24.	Adult Patients Answer Rating ______ 1, 2, 3, or 4	U-5 M-0 L-0	U-25 M-20 L-15	U-50 M-50 L-40	U-25 M-15 L-15	U-10 M-0 L-0	U-5 M-0 L-0

You are asked to estimate the percentage increase, if any, in the average daily number of patients each section could see if a nurse-practitioner were added to the section.

25.	U-27 M-25 L-20	Pediatric Patients	______% Increase in the average daily number patients served	Answer Rating ______ 1, 2, 3, or 4
26.	U-35 M-25 L-15	Adult Patients	______% Increase in the average daily number patients served	Answer Rating ______ 1, 2, 3, or 4

As a final request, you are asked to estimate the number of examination rooms each section should have if it were provided with a nurse-practitioner in addition to a physician.

27.	U-4 M-4 L-3	Pediatric	______	Answer Rating ______ 1, 2, 3, or 4

28. U-4 Adult ________ Answer Rating
M-3
L-3 1, 2, 3, or 4

* * * * * * * * * * * * * *

This second questionnaire involves response with feedback provided from the responses to the first questionnaire. Each question in this second questionnaire is provided with feedback in the form of the median and interquartile range of the groups' response to that same question in the first questionnaire. The median and interquartile statistics are indicated as follows:

U - Upper quartile limit

M - Median

L - Lower quartile limit

You are requested to consider these statistics in making your responses to the questions in this questionnaire. If your response to a question is not within the interquartile range of that question, you may or may not wish to include a brief reason. If you include a reason, please do so on the back of the preceding page and use the question's number for reference. The descriptive material from the first questionnaire has been included for your reference if needed. Your participation in and expedition of this questionnaire will be appreciated by the researcher.

If you finish this questionnaire by Monday, December 15, return it to Dr. Brown's office or give it to your team receptionist and tell her that David Mason will pick it up on Monday, December 15.

APPENDIX III

THE COMPUTER MODELS

The computer models of sequence one and sequence two are divisible into sections which perform particular functions. Some of the sections are common to both the models of sequence one and sequence two. Some of the sections are uniquely associated with only sequence one or only sequence two. Each section is explained along with its effect on any other sections beginning first with sections shared by the two models and concluding with sections differentiating the models of sequence one and sequence two. These models are based upon the conceptual patient flow sequence diagram illustrated in Figure 1.

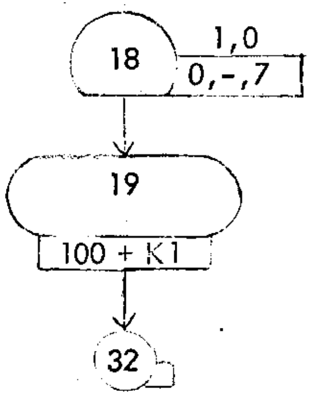
A3.1 Sections Common to the Models of Sequence One and Sequence Two

a. Program Clock

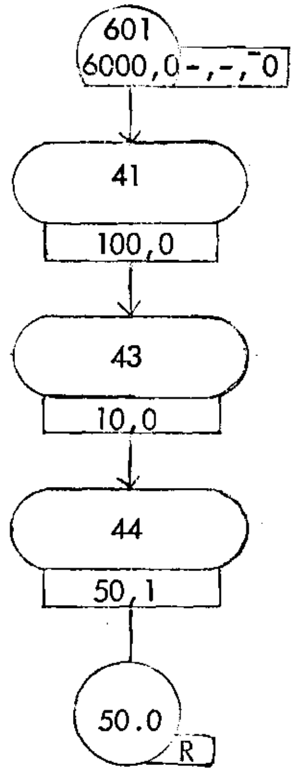
Figure 5A is a block diagram of the clock used in the program. Block number 18 (a GENERATE block) causes one transaction to enter block number 19 (a SAVEX block) every 1/10 minute (or time unit) and causes one unit to be added to X100 the time unit counter.

b. Day Timing

Figure 5B is a block diagram of the system used to restart the system at the end of each simulated day. Block 601 causes one transaction every 6000 time units (or 10 hours) to enter block 4 where X100 is reset to 0 thus restarting the program



A. Program Clock



B. Day Timing

Figure 5. Timing Sections

clock at 0. The transaction proceeds through block 43, resetting X10 to 0 and thus allowing early morning patients to again be generated. The transaction then passes through block 44 which acts as a counter to block 500 (a TERMINATE R block) which is used as a means of stopping the running of the model after the elapse of a predetermined number of days.

c. Walk-in Patient Input

Figure 6 is a block diagram of the walk-in patient input section. This section produces an input of walk-in patients in a pattern resembling that observed at ASCHC.

Block number 700 (a GENERATE block) produces a walk-in patient every 30 minutes with a spread of 15 minutes. (The rate of production, one patient every 30 minutes, is twice that observed for a single medical unit. The rationale for doubling being that the teams were eventually expected to serve twice the volume they were then serving. The spread of 15 minutes was used to randomize the basic input of walk-in patients from block 700.) The patient representing transactions generated by block 700 are routed into blocks 710, 711, 712, 713, 714, 715, 716, 717, or 718, depending upon the hour of the day being simulated. The nine blocks will allow the transaction to proceed into the system on the basis of the observed probable number of walk-in patients expected to arrive during each hour of a simulated day (see Table 2, p. 30). Block 710 represents the hour from 8:00 a.m. to 9:00 a.m., block number 711 from 9:00 a.m. to 10:00 a.m., block 712 from 10:00 a.m. to 11:00 a.m., block 713 from 12:00 noon to 1:00 p.m., block 714 from 1:00

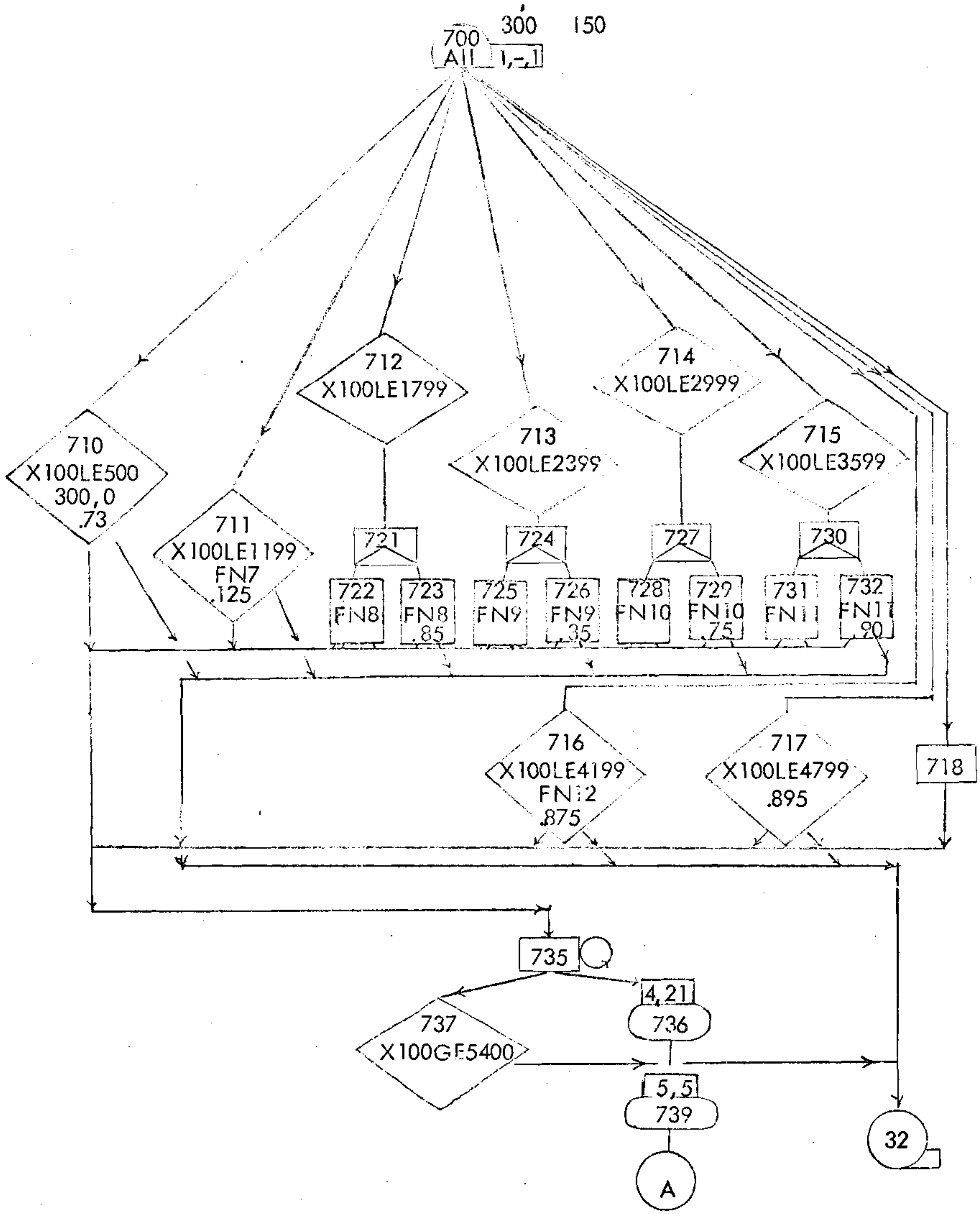


Figure 6. Walk-in Patient Input Section

p.m. to 2:00 p.m., block 715 from 2:00 p.m. to 3:00 p.m., block 716 from 3:00 p.m. to 4:00 p.m., block 717 from 4:00 p.m. to 5:00 p.m., and block 718 represents all time after 5:00 p.m. Blocks 710, 711, 716, and 717 use a probability for allowing transactions to enter the general system. Blocks 712, 713, 714, and 715 use a subroutine to create the more than one transaction which is allowed to enter the general system. Blocks 711 through 716 each have an action time distribution which delays the transactions and allows them to enter the general system in a pattern resembling that observed for each undivided hour. All transactions passing through the above mentioned blocks enter block 735 which is used to record the number entering the system. They then test the status of X100 (the program clock) to see if closing time has been reached; if so, the section is shut down, if not, the transactions proceed through blocks 736 and 739 where parameter values are assigned for later use in determining the amount of examination time required. (See Tables 10, 11, and 12). Lastly, the patient representing transactions are routed into the general system.

d. Appointment Patient Input

Figure 7 is a block diagram of the appointment patient input section. This section produces an input of appointment patients at a rate twice that used at ASCHC. (The rationale again being that ASCHC patient loads per team are expected to double.) The appointment system used conforms to that used at ASCHC. The distribution of patient arrivals about the time of their appointment resembles that observed at ASCHC. (See Table 1, page 29.)

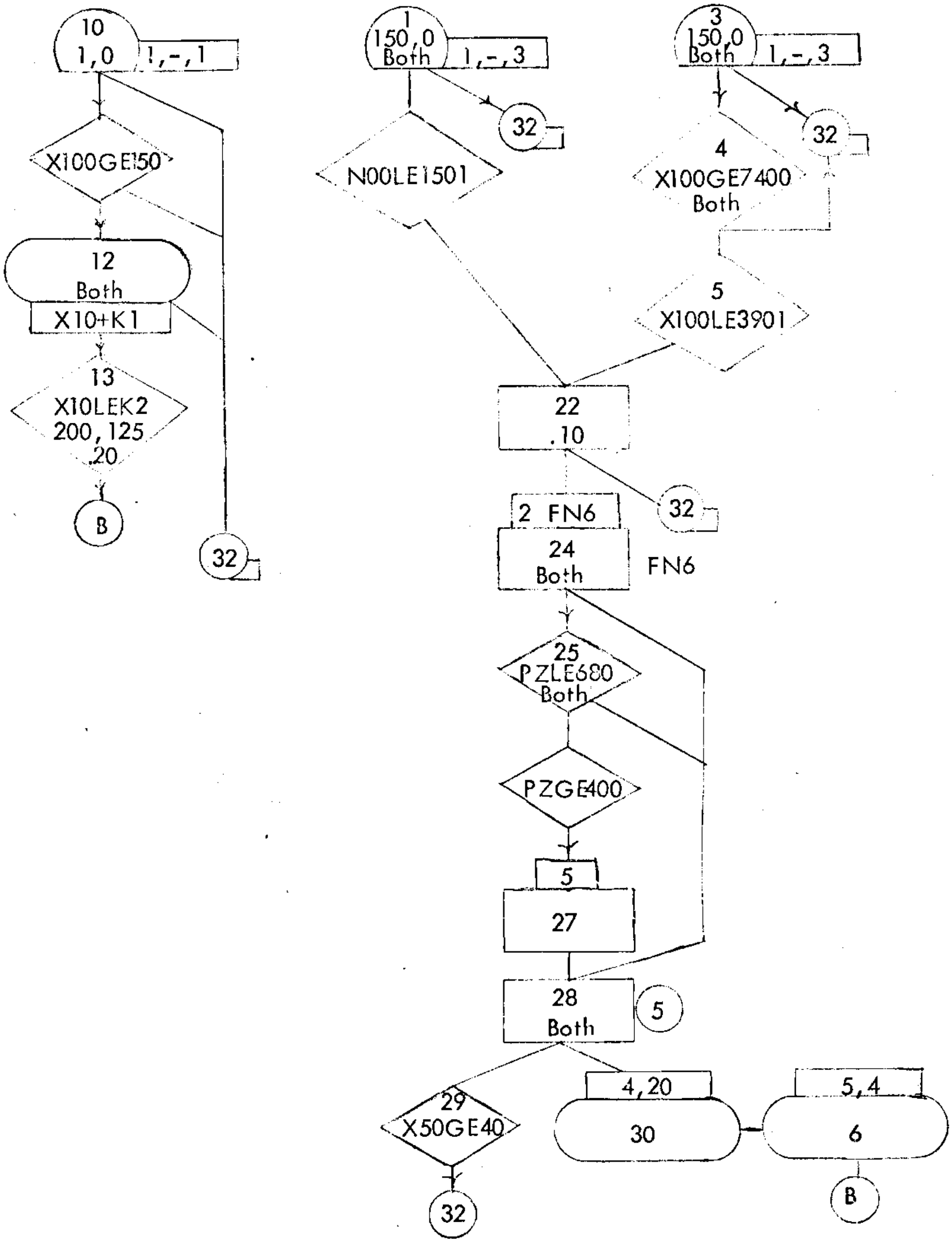


Figure 7. Appointment Patient Input Section

Block number 10 (GENERATE) and the subroutine associated with it (blocks 11, 12, and 13) enter the two patients scheduled before 9:00 a.m. into the system. Block 11 will not permit a patient input before 8:15 a.m. Block 12 counts the number of early morning patients generated. Block 13 limits the number of early morning patients to two. In addition, block 13 handles no-show appointment patients by using the 20% no-show factor characteristic of the early morning appointment patients at ASCHC.

Block number 1 (GENERATE) and number 2 (COMPARE) create the appointment patients scheduled between 9:00 a.m. and 11:30 a.m. (the system used at ASCHC).

Blocks number 3 (GENERATE), number 4 (COMPARE), and number 5 (COMPARE) create the appointment patients scheduled between 1:00 a.m. and 3:30 p.m. (the system used at ASCHC).

Patient representing transactions originating from blocks 2 and 3 enter block 22 where the 10% no-show characteristic of ASCHC appointment patients affects whether or not a transaction continues. After leaving block 22 transactions enter block 24 where they are delayed according to the arrival time distribution about the time of appointment. Blocks 25 and 26 determine if the appointment patient is not more than 20 minutes early or eight minutes late, and block 27 assigns a priority to transactions falling in this category. (ASCHC uses this general method.) Block 28 acts as a counter. Transactions leave block 28 and pass through blocks 30 and 6 where parameter values are assigned for later use in determining the amount of examination time required. Lastly, the transactions are routed to the general system.

e. General Input System Section

Transactions entering this section from the walk-in section enter at A in Figure 8. Those entering from the appointment section enter at B. The receptionist (represented by facility 1) enters the patients into the system (see Table 5, No. 3, p. 40). After entering this section, transactions will pass through block number 33 (COMPARE) until 4:45 p.m. They will then be allowed to enter the system at block 34 (COMPARE) if no patients are waiting; if patients are waiting, a new appointment is scheduled and the patient is removed from the system. (See No. 4 in Table 6.) Transactions leaving blocks 33 and 34 enter block 36 thus releasing the receptionist. Block 37 allows transactions to enter the remainder of the system until 5:00 p.m. at which time all transactions are removed from the system via TERMINATE blocks 32 and 39.

Figure 8 is a block diagram of the general system. This section controls the total patient input into the remainder of the system. This system also stops all patient input at team closing time. (ASCHC procedures were used as this section's basis.)

f. Physician Section

Figure 9 is a block diagram of the physician section, common to both sequence one and sequence two. The physician is represented by a separate block diagram which is connected to the flow of patients only by logic links. The physician is a key individual in both sequences. The availability of the physician, however, is not directly related to the patient flow but depends in part upon personal needs and requests for consultation. The use of a separate block diagram allowed the physician to be simulated as an independent individual.

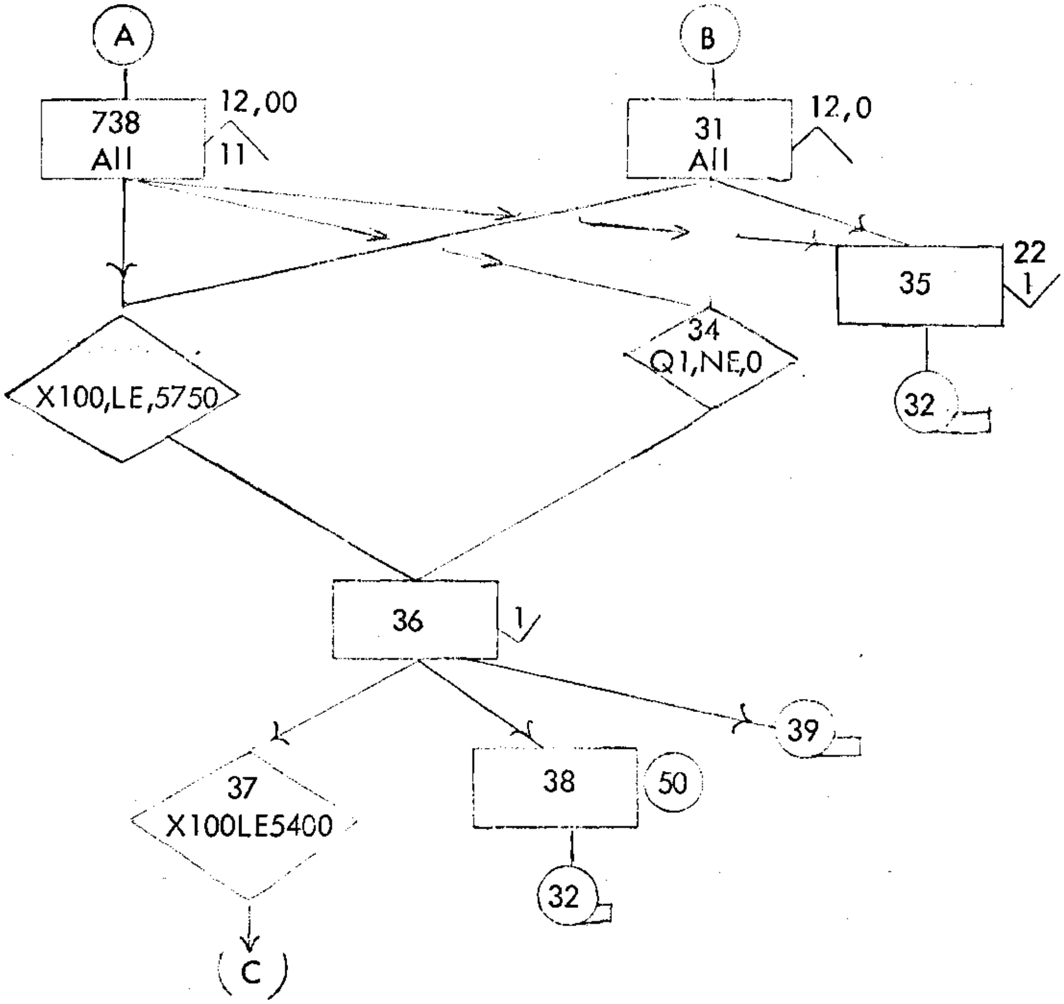


Figure 8. General Input System Section

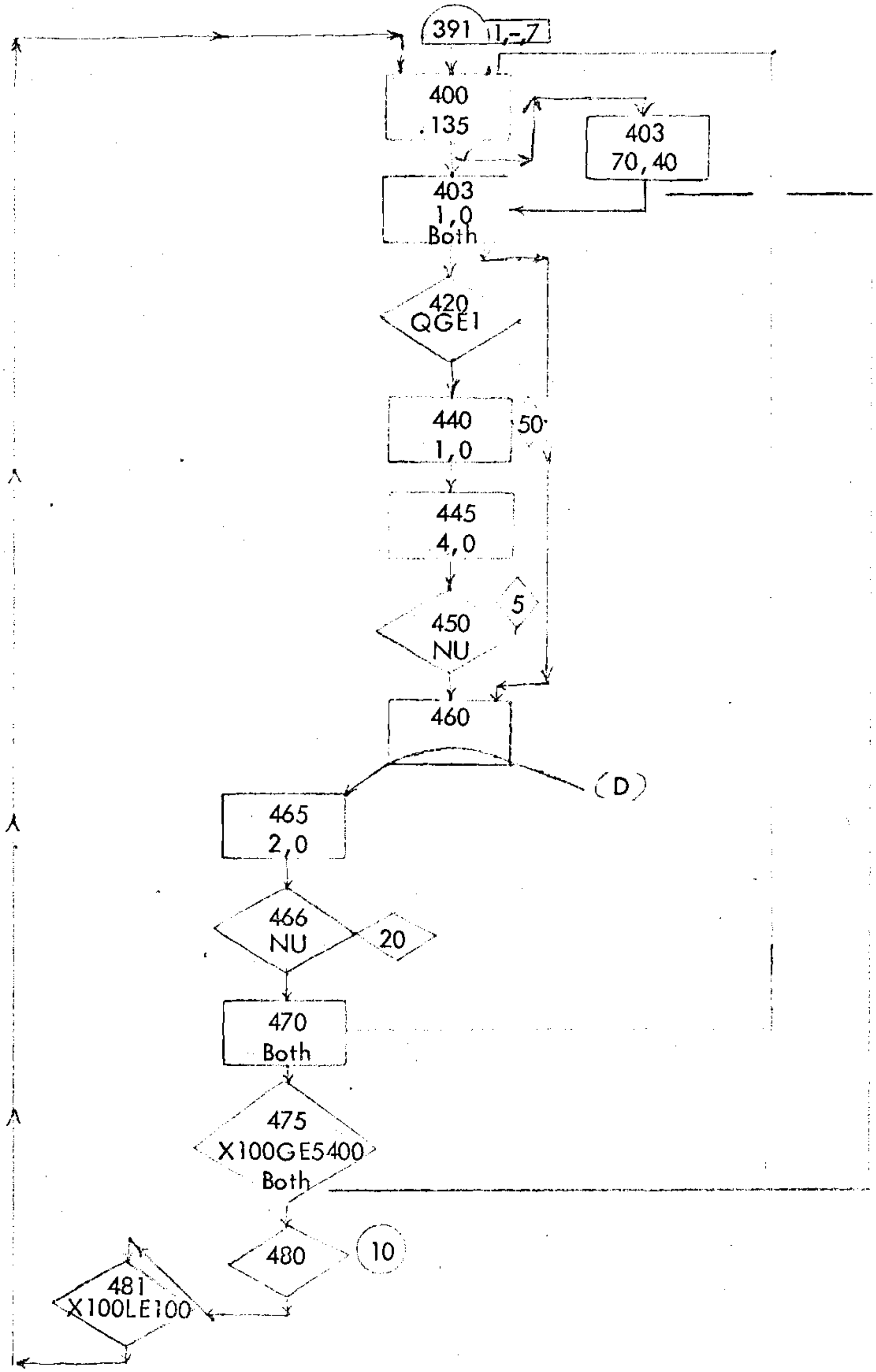


Figure 9. Physician Section

A single transaction representing the physician is generated by block 391 (GENERATE). This transaction then acting as the physician, flows in a series of loops through the block diagram which represents the activities of the physician. All loops through the block diagram except those occurring after X100=5400 (5:00 p.m.) begin at block 400. From block 400 transactions are routed to block 403 86.5% of the time. They are routed to block 401 13.5% of the time and then to block 403. Block 401 simulates consultation by the physician. (13.5% of a physician's time is devoted to consultation (Tables 5 and 6)).

Transactions from block 403 first attempt to pass through block 420 (COMPARE). Block 420 is the entrance into the examination section which simulates the fact that a physician is not subject to interruptions during a patient examination. Block 420 tests the status of QUEUE 3 and allows the physician transaction to proceed through the examination section only if a patient transaction is waiting to proceed to the examination block. When no patients are indicated as needing examination the physician transaction is routed to block 460 thus by-passing the patient examination section. After passing through block 420, the physician transaction enters block 440 (facility 50) which signals the patient transaction to proceed to the examination block. The transaction from block 440 is delayed at block 445 while examination is begun. Block 450 delays the physician transaction's progress until the patient transaction has left the examination block, thus indicating the end of examination. From block 450 the transaction proceeds to block 460. Block 460 (SPLIT) splits the physician transaction producing two transactions. One transaction is sent through a subroutine, beginning at D, which schedules the lunch break. The other transaction is routed to block 465. The transaction is not allowed to leave block 465 if the physician is at lunch. From block 465 the physician transaction proceeds through blocks 466 and 470 looping back to block 400 until block 475 indicates that the time is after 5:00 p.m. (X100,GE,5400). After 5:00 p.m. physicians are no longer subject to consultation but devote full time to examination until all remaining patients have been examined. Physician transations, therefore, leaving block 475 are routed to block 403 until block 480 indicates that no more patients remain to be seen (all examining rooms are empty). The physician transaction enters block 480 after all patient transactions have been processed. Block 481 allows the physician transaction to leave block 480 and return to block 400 at the beginning of the simulation of another day's operation.

g. Physician Lunch Break Section

Figure 10 is a block diagram of the lunch break section used in sequence one of the physician's section. The sequence two section is very similar and is not described in detail. Transactions which originate from block 460 (Figure 9) enter this section at point D. Block 520 (COMPARE) causes all transactions to be terminated until the simulation clock exceeds 12:00 noon (X100,GE,2400). The first transaction thereafter is allowed to enter block 60 (HOLD) which delays its progress analogously to the physician's lunch break. All other transactions are destroyed. After elapse of the lunch duration delay the transaction enters block 570 which signals that the physician has returned from lunch and is again available to see patients. Block 571 clears this section at the beginning of another day's simulated operation.

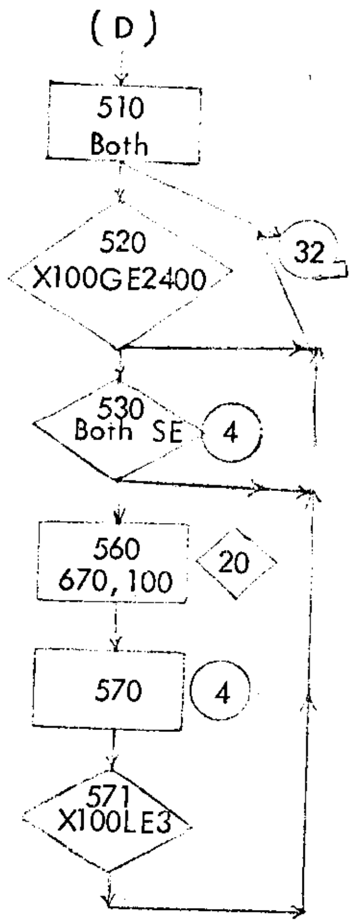


Figure 10. Physician Lunch Break Section

A3.2 Sequence One Sections

These sections represent the conceptual interpretation of sequence one as it should operate. Figure 11 is a block diagram of the patient flow and testing sections in sequence one. This section processes patients according to the concepts of sequence one.

a. Patient Flow Section

Patient representing transactions enter sequence one at point C, the end of the general patient input system. Transactions first enter block 50 (SPLIT) which separates from the original transaction a transaction that is routed to block 70 for testing purposes (described later). From block 50 transactions proceed to block 60 (QUEUE) which represents the patient waiting room. Blocks 150, 151, and 152 receive a signal from block 142 in the testing section that one examining room is available and allows one transaction to leave block 60 and enter block 170, which signifies the occupying of one examining room. A storage (number 10) is used to represent the number of examining rooms available for a medical unit. A transaction entering block 170 fills one unit of storage (represent a room). The units of storage provided is equal to the number of examining rooms provided. Block 53 is used to purge the system of transactions when the model is restarted after having simulated one day's operation.

Transactions from block 170 enter block 180 where they are delayed. Block 180 is used to represent time required for the preparation of the patient for examination and the recording of the patient's medical history. (Function 3, taken

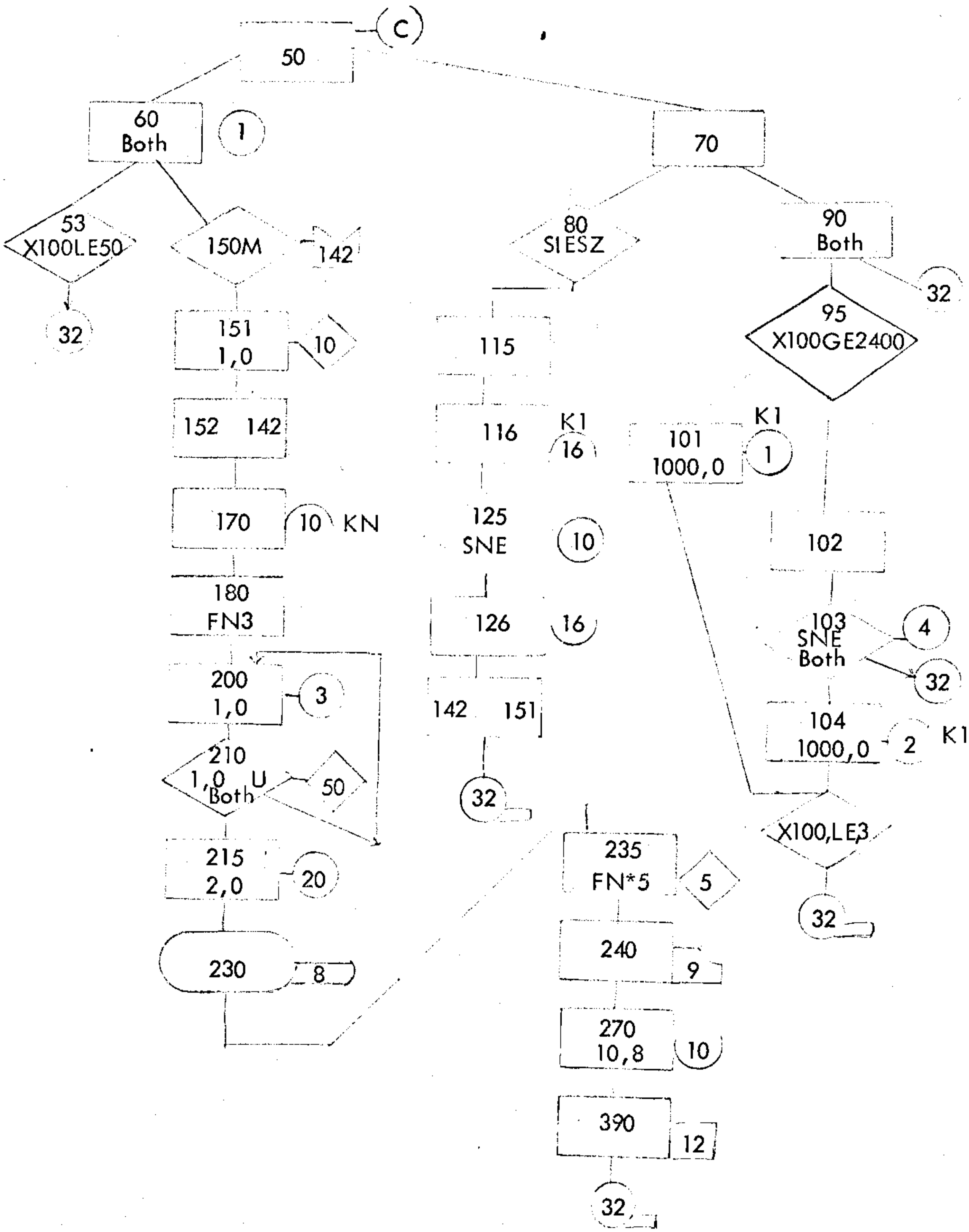


Figure 11. Sequence One Patient Flow Section

from Table 6, A (1)) is used to delay the transactions in a pattern resembling that observed at ASCHC.) After passing through block 180 the transactions enter block 200, which is representative of the waiting by patients after having been prepared for examination for the physician.

Blocks 210 (GATE) and 215 (STORE) allow only one transaction to leave block 200 whenever the physician becomes available to service a patient. (Block 210 tests the status of facility 50 which is in use only if a physician is available, that is block 440 is occupied.)

Block 235 (HOLD, facility No. 5) is used to represent the patient examination time. Two functions (Nos. 4 and 5) are used for determining the number of time units that transaction is delayed in block 235 signifying examination by the physician.

Both functions 4 and 5 were developed during the Delphi section of this study and are presented in Tables 11 and 12 where they are listed under the sequence one category. Table 11 data are used when studying the pediatric medical unit and Table 12 data are used for evaluation of the adult unit.

Transactions leaving block 235 pass through block 240 and enter block 270 (LEAVE) which, after the elapse of time units representing the time required to clear a room after the physician leaves (see Table 6, No. 5), increases the number of available open examining rooms by one.

b. Testing Section

This section tests the availability of at least one examination room and in addition stops patient input when the physician goes to lunch and tests to determine when the physician returns from lunch.

Transactions entering block 70 (SPLIT) are split with one going to block 80 and the other to block 90. The transactions pass through block 80 (COMPARE) only when the physician is not at lunch. Otherwise they are delayed. From block 80 transactions proceed to block 115 and then through blocks 116, 125, and 126 to block 142 only when at least one examining room is available. Block 142 signals block 150 that one examining room is available, thus allowing one transaction to leave block 60 (signifying the waiting room).

Transactions entering block 90 are destroyed until the clock time (X100) exceeds 2400 (12:00 noon). They then proceed through block 95 to first block 101 (STORAGE No. 2). At this point no transaction may leave block 60. The remaining transactions are routed through blocks 102, and 103 to 105 which tests (block 103, GATE) to determine when the physician returns from lunch and again permits transactions to leave block 60.

Block 105 is used to clear the system when the model is restarted after having simulated one day's operation.

A3.3 Sequence Two Sections

These sections represent the conceptual interpretation of sequence two as it is expected to exist in the operational state. The section processes patients according to the concepts of sequence two as described in Chapter IV and illustrated in Figure 1.

Figures 12 and 13 are block diagrams of the patient flow sections of sequence two. Figure 14 is a block diagram of the testing section of sequence two

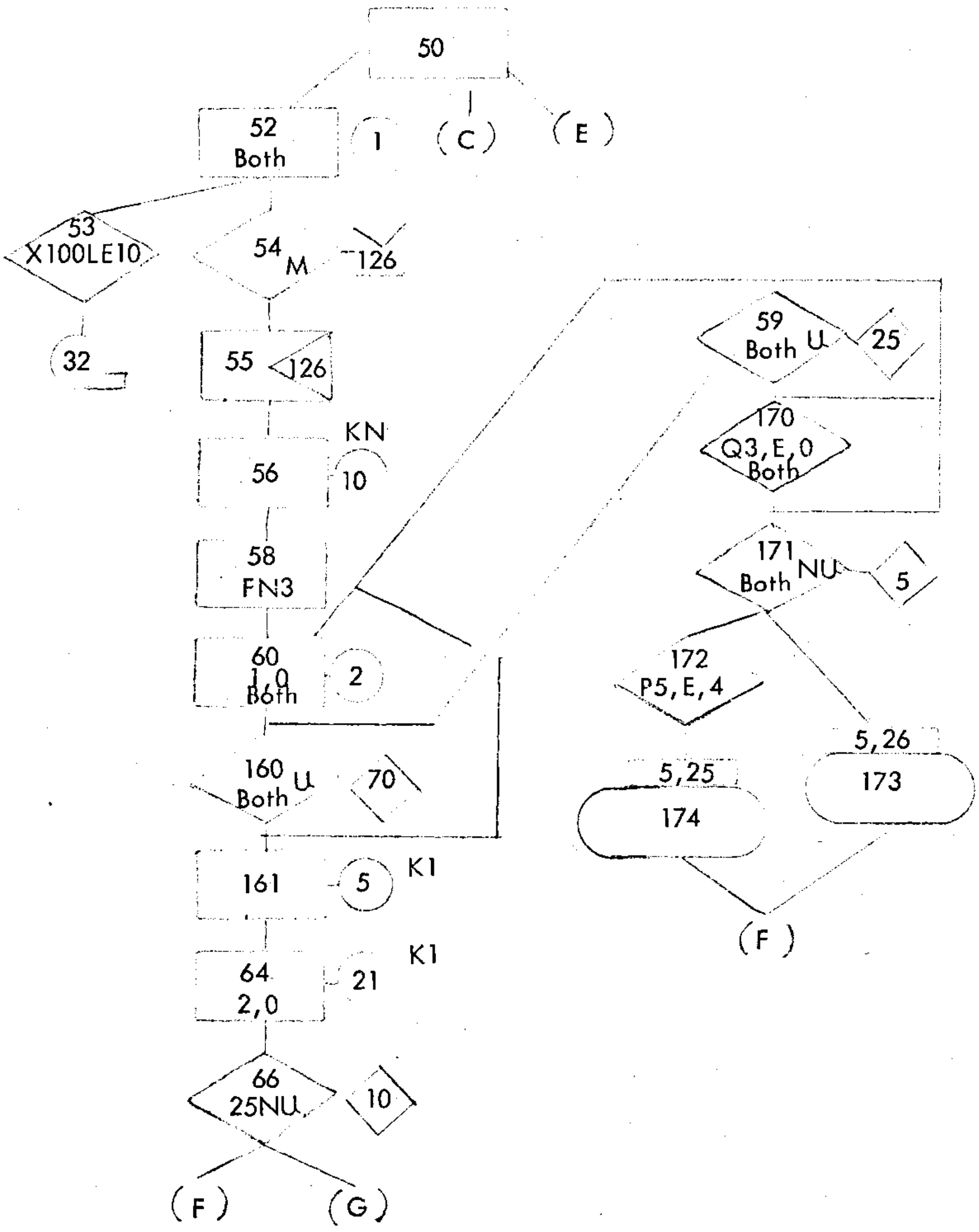


Figure 12. Sequence Two Patient Flow Section

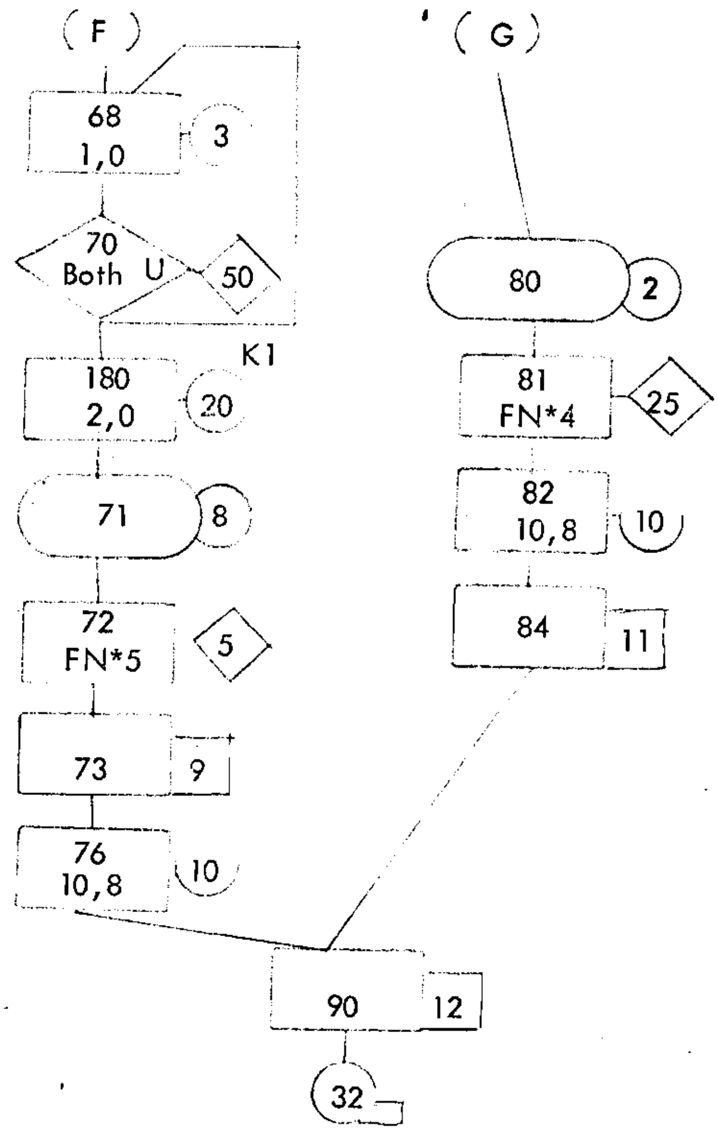


Figure 13. Sequence Two Patient Examination Section

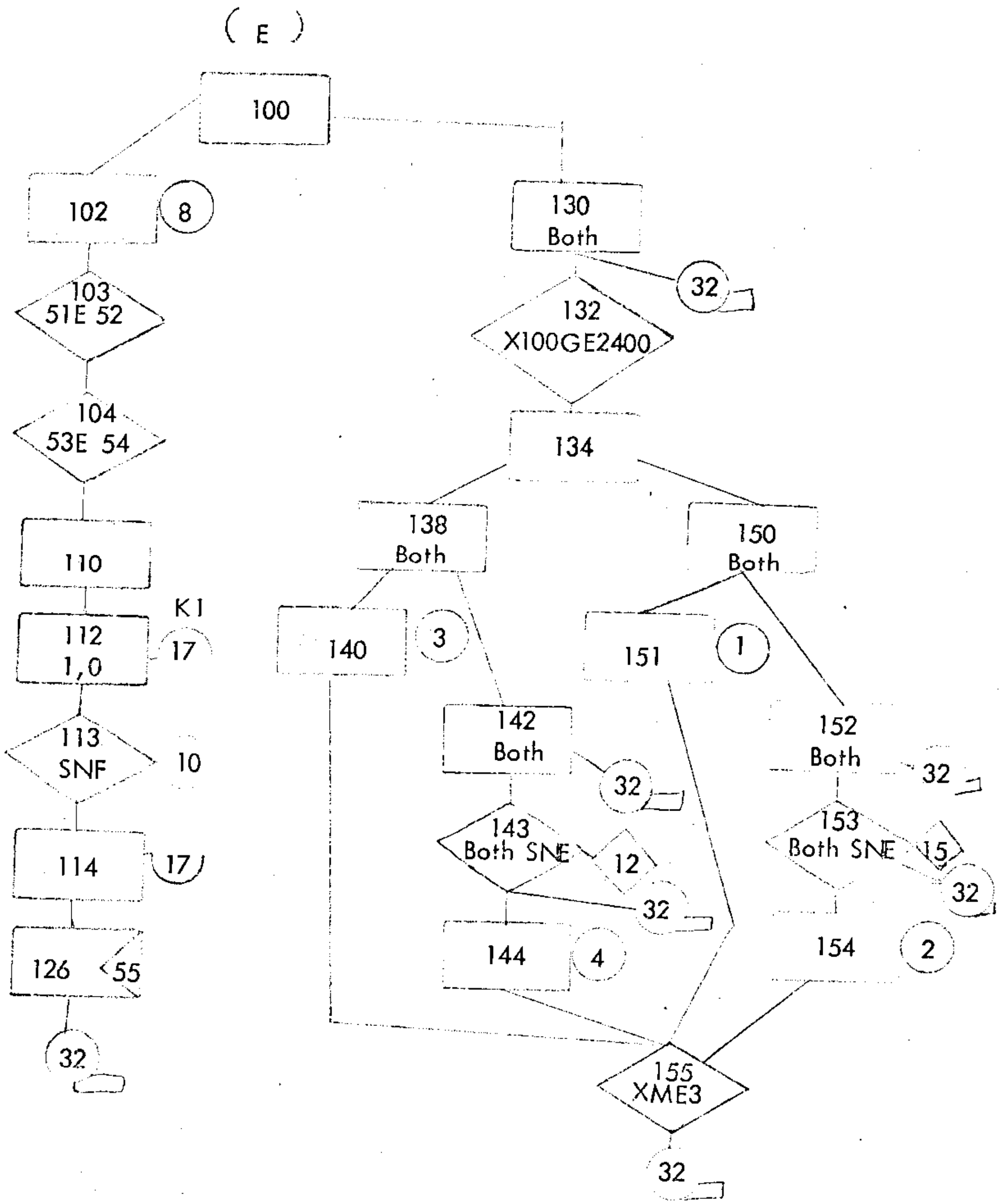


Figure 14. Sequence Two Testing Sections

and figure 15 is a block diagram of the nurse-practitioner section (unique to sequence two).

a. Patient Flow Section

Patient representing transactions enter sequence two at point C (see Figure 15). They then enter block 50 (SPLIT) which separates from each original transaction another transaction. The original transaction proceeds through the patient flow sections and the second transaction is routed to the testing section via point E. From block 50 the original transactions proceed to block 52 (QUEUE No. 1) which represents a waiting room. One transaction is allowed to leave QUEUE No. 1 (block 52) when a signal has been received by block 54 (GATE) that one examining room is available. The transaction then proceeds through block 55, thereby resetting the testing section's block 126 to zero, to block 56. At block 56 the transaction fills one unit of space in storage No. 10, if available. The procedure is analogous to a patient being placed in the first examining room that is available. The capacity of storage No. 10 equals the number of examining rooms provided. From block 56 transactions proceed to block 58 where they are delayed to simulate the preparation of the patient for examination with recording the patient's medical history. They then proceed to block 60 (QUEUE No. 2) which represents a patient's waiting after preparation.

Leaving block 60 transactions may take two alternative routes: (1) If the nurse is indicated as being available to screen patients (facility 70 in use) transactions proceed through blocks 160 (GATE) and 161 to block 64. (2) If the nurse

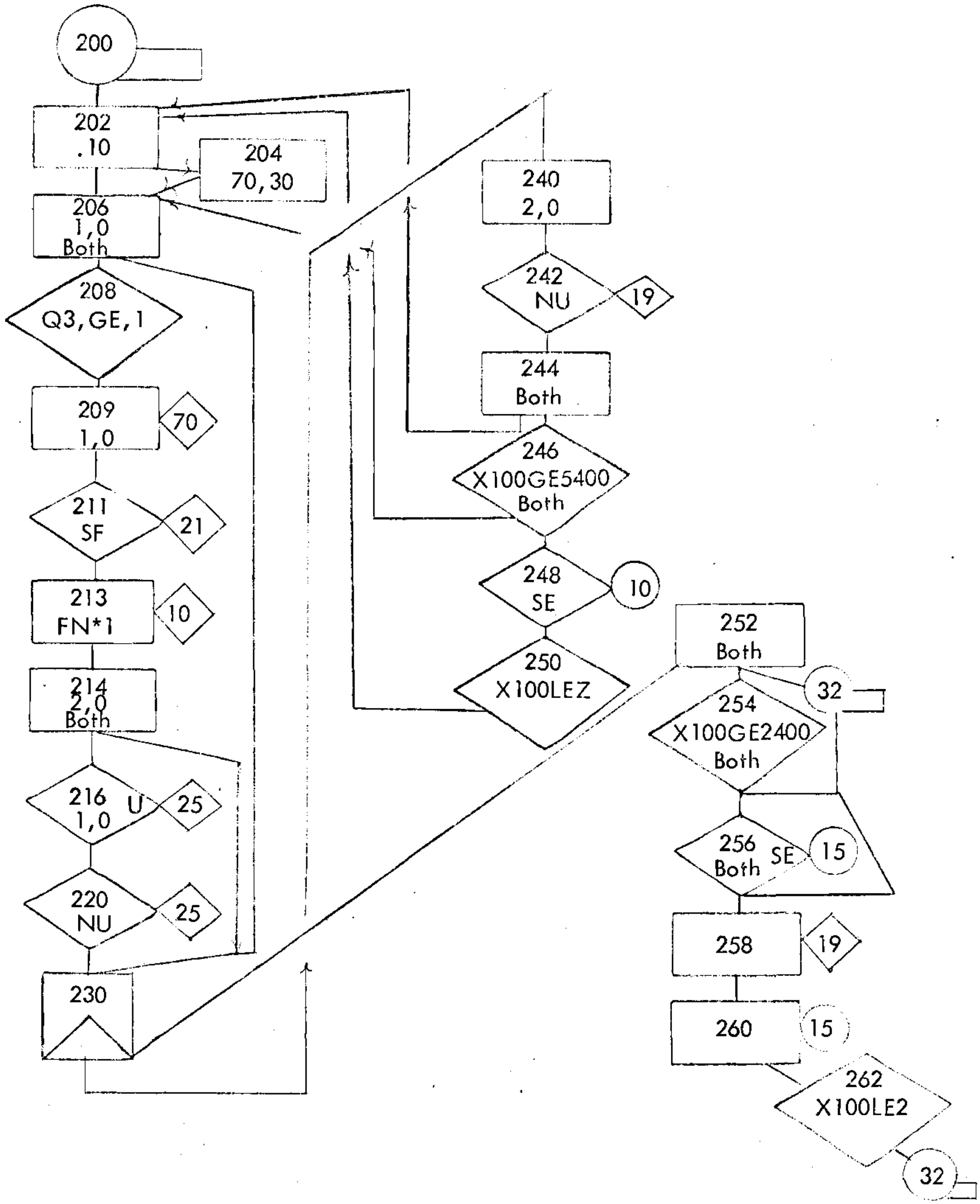


Figure 15. Sequence Two Nurse Section

is not available the transactions test at block 59 (GATE) to determine if the nurse is examining a patient and if so proceeds through block 59. If neither route is open the transactions are delayed at block 60.

The route through block 59 by-passes the nurse entirely if the physician has no patients waiting (transactions process through block 170) and is not examining a patient (transactions process through block 171). If either above condition is not met, transactions are returned to block 60. Blocks 172, 174, and 173 reassign the physician examination time parameters to indicate that the patients have not been screened. From blocks 174 and 173 transactions enter the physician examination section at point F.

The route through block 64 involves waiting for the nurse to screen the patients. Transactions are allowed to process through block 66 when the screening has been completed. Leaving block 66 transactions are routed probabilistically for nurse examination (via point G) or for physician examination (via point F). The probability of taking route G, nurse examination, was developed from Delphi and is .25 for adult patients and .20 for pediatric patients.

Figure 13 is a block diagram of the patient examination sections (physician and nurse) of the patient flow section and is an extension of the block diagram illustrated in Figure 12. The physician examination section begins at point F, the nurse section at point G.

Block 68 represents the waiting by patients in the examining rooms after screening for the physician. Blocks 70 (GATE) and 180 allow one transaction to proceed to block 72 when the physician is available for examination. At block 72 (HOLD, facility No. 5) the number in parameter No. 5 is used to determine which physician examinations service time distribution is to be used for determining the duration of the examination simulating delay. There are four such distributions, all of which were determined by Delphi and are listed in Tables 11 and 12. From block 72 transactions proceed to block 76 (RELEASE) where the number of available examining rooms is increased by one. Transactions are then terminated.

Block 81 (HOLD, facility No. 25) represents nurse examination. Transaction parameter No. 4 is used to select one of two examination service time distributions, both of which were developed by Delphi and are found in Table 13. From block 81 transactions proceed through block 82 (RELEASE) where after a short delay the number of available examining rooms is increased by one. Transactions are then terminated.

b. Testing Section

Figure 14 is a block diagram of the sequence two testing section. This section tests the availability of at least one examining room and signals the patient flow section (at block 54) when one is available. In addition, the patient flow is stopped at 12:00 noon (X100,GE,2400), block 132, and is not allowed to restart until both the physician and nurse are indicated as again being available.

Transactions enter this section at block 100 (SPLIT) from which one test transaction is routed to block 102, the other to block 130. From block 102 transactions proceed through blocks 103 and 104 to block 110 if both the physician and nurse are not indicated as being at lunch. Transactions proceed from block 110 to block 126 if at least one examining room is available. Transactions leaving block 126 are terminated.

Transactions entering block 130 are not terminated until clock time (X100) exceeds 2400 (12:00 noon). They then proceed through block 132 to block 134 (SPLIT) where they are split--one half going to block 138 for testing the status of the physician's lunch break, the other half going to block 150 for testing the status of the nurse's lunch break. The procedure used is the same as that described in the testing section of sequence one, page 110.

c. Nurse Section

Figure 15 is a block diagram of the nurse or nurse practitioner section of sequence two. A separate section was used for the nurse as for the physician to simulate an independent individual. The structure of this section is similar to the physician section. A single transaction representing the nurse is generated by block 200 (GENERATE). This transaction loops through the system represented by the block diagram which represents the expected daily functions of a nurse.

The route from block 202 is to block 206 90% of the time and to block 204 10% of the time. Block 204 simulates personal breaks which are assumed to occur with a 10 probability.

From block 206 the transaction is routed through block 208 if a patient is waiting to be screened (Q3,GE,1), block 208; otherwise it is routed to block 230. Block 208 is the entrance into the screening and examination section. Blocks 209 and 211 coordinate the beginning of the screening which occurs in block 213. Block 214 delays the nurse transaction for two time units to allow the patient transaction to be routed to either the physician or nurse for examination. From block 214 the nurse transaction will be allowed to proceed through block 216 if the nurse is examining the patient; if not, the transaction is routed to block 230. After the nurse examination is completed, transactions routed through block 216 are allowed to proceed through block 220 to block 230.

The transaction route through blocks 240, 242, 244, 246, 248, and 250 is identical to that described in the physician section blocks 465, 466, 470, 480, and 481 respectively.

The functions of blocks 252, 254, 256, 258, 260, and 267 are identical to those described in the physician lunch break section.

A3.4 Sample Program Listings

Sample program listings of Sequence One and of Sequence Two are found on the following pages.

```
 22   ADVANCE                                .10  24    K2
 6    FUNCTION     RN1   C16   PEDIATRIC APPOINTARRIXL
0.0   100    .04   237   .065  513    .119  400   .185  480   .260  530
.350  570    .460  588   .590  600    .662  620   .760  548   .852  680
.910  618    .960  780   .988  840    1.0   900
 24   ASSIGN       2     FN6          BOTH  25    P8    1     FN6
 25   COMPARE      P2    LE    K680   BOTH  26    P8
 26   COMPARE      P2    GE    K400         27
 27   PRIORITY     5                        28
 28   QUEUE        5                  BOTH  29    30
 29   COMPARE      X50   GE    K4           32
 30   ASSIGN       4     K20                6
 6    ASSIGN       5     K4                 31
 31   SEIZE        1                  ALL   33    35    12
 32   TERMINATE
* STOP PATIENT INPUT AT 15 MIN, BEFORE CLOSING TIME
 33   COMPARE      X100  LE    K5250        36
* ALLOW PATIENTS TO ENTER IF NONE ARE WAITING
 34   COMPARE      Q1    NE    K0           36
* SCHEDULE A NEW APPOINTMENT FOR A PATIENT
 35   RELEASE      1                  BOTH  38    32    22
 36   RELEASE      1                  ALL   37    39
* STOP ALL PATIENT INPUT AT CLOSING TIME
 37   COMPARE      X100  LE    K5400        50
* SUB-ROUTINE TO ALLOW SYSTEM TO CLEAR AT THE END OF EACH DAY
* AND RESTART THE SYSTEM FOR ANOTHER DAY
 38   STORE        50                       32
 39   TERMINATE
 40   GATE         SE10                     41          100
 41   SAVEX        100   K0                 43
 43   SAVEX        10    K0                 44
 44   SAVEX        50    K1                 500
 500  TERMINATE    3
 50   SPLIT                                 52    100
* WAITING ROOM
 52   QUEUE        1                  BOTH  53    54
 53   COMPARE      X100  LE    K10          32
* RECEIVES SIGNALS--ONE ROOM AVAILABLE--EXAMINER NOT AT LUNCH-----
 54   GATE         M126                     55
 55   MATCH        126                      56
* REDUCES NUMBER OF AVAILABLE ROOMS BY ONE
 56   ENTER        10                       58
* PREPARE PATIENT FOR EXAMINATION
 3    FUNCTION     RN1   D5
.170  10     .62   22    .84   35     .94   47    1.0   61
 58   ADVANCE                               60    1     FN3
* PATIENT WAITING IN ROOM FOR EXAMINATION BY NURSE
 60   QUEUE        2                  BOTH  160   59    1
 160  GATE         U70                BOTH  161   60
 161  STORE        5                  BOTH  64    59
*     IF THE NURSE IS TREATING A PATIENT AND THE PHYSICIAN IS NOT
*   TREATING A PATIENT AND HAS NO SCREENED PATIENTS WAITING  THE
*     PATIENTS WILL BE ROUTED TO THE PHYSICIAN   FOR TREATMENT.
 59   GATE         U25                BOTH  170   60
 170  COMPARE      Q3    E     K0     BOTH  171   60
 171  GATE         NU5                BOTH  172   173
 172  COMPARE      P5    E     K4           174
```

```
 445  ADVANCE                                        450            6
 450  GATE       LS6                                 460
 460  SPLIT                                          465    *10
 465  ADVANCE                                        466            1
 466  GATE       LU20                                470
 470  ADVANCE                                  BOTH  475    609
 475  COMPARE    X100   GE     K5400   BOTH          480    603
 480  GATE       SF10                                481
 481  COMPARE    X100   LE     K100                  490
* SUB-ROUTINE----ALLOW BREAK FOR LUNCH
 510  ADVANCE                            BOTH        520    *2
 520  COMPARE    X100   LE     K2400     BOTH        522    *2
 522  COMPARE    P3     E      K0        BOTH        530    *2      3
 530  GATE       SE12                                540
 540  SAVEX      90+    1                BOTH        545    *2
 545  COMPARE    X90    E      K1                    560
 560  HOLD       2                                   570            670    100
 570  STORE      12                                  571            100
 571  COMPARE    X100   LE     K3                    572
 572  SAVEX      90     K0                           32
************ WALK-IN PATIENT INPUT SUB-ROUTINE **************
 710  COMPARE    X100   LE     K599    .750          735    *2      300    50
 7    FUNCTION   RN1    D4
.295  150   .715  300   .935   450     1.0           600
 711  COMPARE    X100   LE     K1199   .125          735    *2      1      FN7
 712  COMPARE    X100   LE     K1799                 721
 721  SPLIT                                          722    *23
 8    FUNCTION   RN1    D4
.290  150   .60   300   .820   450     1.0           600
 722  ADVANCE                                        735            1      FN8
 723  ADVANCE                          .95           735    *2      1      FN8
 713  COMPARE    X100   LE     K2399                 724
 724  SPLIT                                          725    *26
 9    FUNCTION   RN1    D4
.360  150   .445  300   .840   450     1.0           600
 725  ADVANCE                                        735            1      FN9
 726  ADVANCE                          .35           735    *2      1      FN9
 714  COMPARE    X100   LE     K2999                 727
 727  SPLIT                                          728    *29
 10   FUNCTION   RN1    D4
.312  150   .53   300   .765   450     1.0           600
 729  ADVANCE                                        735            1      FN10
 728  ADVANCE                          .75           735    *2      1      FN10
 715  COMPARE    X100   LE     K3599                 730
 730  SPLIT                                          731    *32
 11   FUNCTION   RN1    D4
.280  150   .525  300   .830   450     1.0           600
 731  ADVANCE                                        735            1      FN11
 732  ADVANCE                          .90           735    *2      1      FN11
 12   FUNCTION   RN1    D4
.320  150   .490  300   .795   450     1.0           600
 716  COMPARE    X100   LE     K4199   .875          735    *2      1      FN12
 717  COMPARE    X100   LE     K4799   .895          735    *2      150
 718  ADVANCE                                        735
 735  QUEUE      6                       BOTH        737    *36
 737  COMPARE    X100   GE     K5400                 32
 736  ASSIGN     4      K21                          739
```

```
739  ASSIGN        5       25                   738
738  SEIZE         1                     TL     33     *5     60     13
600  TERMINATE
     START         3             ,8100

CLOCK TIME  REL        13000                 ABS        13000
```

TRANS COUNTS

BLOCK	TRANS, TOTAL	BLOCK	TRANS, TOTAL	BLOCK	TRANS, TOTAL	BLOCK	TRANS, TOTAL	BLOCK	TRANS, TOTAL
1	0, 120	2	0, 31	3	0, 120	4	0, 72	5	0, 31
6	0, 63	7	0, 0	8	0, 0	9	0, 0	10	0, 17999
11	0, 17552	12	0, 17552	13	0, 6	14	0, 1	15	0, 1
16	0, 0	17	0, 0	18	0, 17999	19	0, 17999	20	0, 0
21	0, [illegible]	22	0, 62	23	0, 0	24	0, 57	25	0, 52
26	0, 44	27	0, 44	28	0, 57	29	0, 0	30	0, 63
31	0, 63	32	0, 37399	33	0, 111	34	0, 2	35	0, 0
36	0, 115	37	0, 112	38	0, 1	39	0, 0	40	0, 0
41	0, 3	42	0, 0	43	0, 3	44	0, 3	45	0, 0
46	0, 0	47	0, 0	48	0, 0	49	0, 0	50	0, 112
51	0, 0	52	0, 112	53	0, 6	54	0, 104	55	0, 104
56	0, 104	57	0, 0	58	1, 104	59	0, 1601	60	1, 1687
61	0, [illegible]	62	0, 0	63	0, 0	64	1, 83	65	0, 0
66	0, 8[illegible]	67	0, 0	68	0, 99	69	0, 0	70	0, 99
71	0, 82	72	0, 82	73	0, 82	74	0, 0	75	0, 0
76	0, 82	77	0, 0	78	0, 0	79	0, 0	80	0, 19
81	0, 19	82	0, 19	83	0, 0	84	0, 19	85	0, 0
86	0, 0	87	0, 0	88	0, 0	89	0, 0	90	0, 100
96	0, 0	97	0, 0	98	0, 0	99	0, 0	100	0, 112
101	0, 0	102	0, 112	103	0, 112	104	0, 112	105	0, 0
106	0, 0	107	0, 0	108	0, 0	109	0, 0	110	1, 112
111	0, 0	112	1, 111	113	0, 110	114	0, 110	115	0, 0
126	6, 11[illegible]	127	0, 0	128	0, 0	129	0, 0	130	0, 112
131	0, 0	132	0, 55	133	0, 0	134	0, 55	135	0, 0
136	0, 0	137	0, 0	138	0, 55	139	0, 0	140	1, 3
141	0, 0	142	0, 52	143	0, 38	144	1, 3	145	0, 0
146	0, 0	147	0, 0	148	0, 0	149	0, 0	150	0, 55
151	1, 3	152	0, 52	153	0, 46	154	1, 3	155	0, 8
156	0, 0	157	0, 0	158	0, 0	159	0, 0	160	0, 85
161	0, 83	162	0, 0	163	0, 0	164	0, 0	165	0, 0
166	0, 0	167	0, 0	168	0, 0	169	0, 0	170	0, 1404
171	0, 19	172	0, 13	173	0, 5	174	0, 13	175	0, 0
176	0, 0	177	0, 0	178	0, 0	179	0, 0	180	0, 82
196	0, 0	197	0, 0	198	0, 0	199	0, 0	200	0, 1
201	0, 0	202	0, 209	203	0, 0	204	0, 31	205	0, 0
206	0, 369	207	0, 0	208	0, 69	209	0, 69	210	0, 0
211	0, 69	212	0, 0	213	1, 69	214	0, 68	215	0, 0
216	0, 18	217	0, 0	218	0, 0	219	0, 0	220	0, 18
226	0, 0	227	0, 0	228	0, 0	229	0, 0	230	0, 368
236	0, 0	237	0, 0	238	0, 0	239	0, 0	240	0, 368
241	0, 0	242	0, 369	243	0, 0	244	0, 368	245	0, 0
246	0, 81	247	0, 0	248	0, 0	249	0, 0	250	0, 0
251	0, 0	252	0, 368	253	0, 0	254	0, 209	255	0, 0
256	0, 3	257	0, 0	258	0, 3	259	0, 0	260	1, 3
261	0, 0	262	0, 2	263	0, 0	264	0, 0	265	0, 0
391	0, 1	392	0, 0	393	0, 0	394	0, 0	395	0, 0
396	0, 0	397	0, 0	398	0, 0	399	0, 0	400	0, 297
401	0, 38	402	0, 0	403	0, 441	404	0, 0	405	0, 0
416	0, 0	417	0, 0	418	0, 0	419	0, 0	420	0, 82

```
 173  ASSIGN      5    K26                 68
 174  ASSIGN      5    K25                 68
* TEST FOR NURSEREADINESS TO EXAMINE
* PATIENT EXAMINATION  SCREENING
 64   STORE       21                       66          2
* RECEIVES SIGNAL EXAMINATION  TERMINATED
 66   GATE        U10             .20      68    20                    PEDIATRIC
* PATIENT WAITING IN ROOM FOR EXAMINATION BY M.D.
 68   QUEUE       3                        70          1
* TEST FOR M.D. READINESS TO EXAMINE
 70   GATE        U50             BTH      180   68
 180  STORE       20                       71          2
 71   MARK        5                        72
* ACTUAL EXAMINATION
 4    FUNCTION    RN1   C6   PEDIATRIC APPOINTMENTS --MD-- SCREENED
0.0   50   .182   100  .458  150  .820  200  .956  250  1.0  300
 5    FUNCTION    RN1   C7   PEDIATRIC WALK-IN ---MD--- SCREENED
.0    0.0  . 43   50   .256  100  .641  150  .898  200  .993  250
1.0   300
 25   FUNCTION    RN1   C7   PEDIATRIC APPOINTMENTS --MD-- NOT SCREENED
.0    00   .131   50   .189  100  .611  150  .821  200  .947  250
1.0   300
 26   FUNCTION    RN1   C6   PEDIATRIC WALK-IN --MD-- NOT SCREENED
.0    50   .143   100  .514  150  .889  200  .981  250  1.0  300
 72   HOLD        4                        73          1     FN*5
* TABULATE EXAMINING TIME
 73   TABULATE    9                        76
* FREE ONE ROOM
 76   LEAVE       10                       90          10    8
 80   MARK        2                        81
* PATIENT EXAMINATION
 20   FUNCTION    RN1   C4   PEDIATRIC APPOINTMENTS SEEN BY NURSE
0.0   50   .10    100  .50   150  .90   200
 21   FUNCTION    RN1   C4   PEDIATRIC WALK-IN  SEEN BY NURES
0.0   50   .177   100  .667  150  1.0   200
 81   HOLD        25                       82          1     FN*4
* FREE ONE ROOM
 82   LEAVE       10                       84          10    8
* TABULATE EXAMINING TIME
 84   TABULATE    11                       90
 90   TABULATE    12                       32
* STOP PATIENTS AT 12:00 AND RESTART WHEN M.D. RETURNS LUNCH
 100  SPLIT                                102   130
 103  COMPARE     51    E    K2            104
 102  QUEUE       2                        103
 104  COMPARE     53    E    K4            110
 110  ADVANCE                              112
 112  ENTER       17                       113         1
* TESTING FOR A ROOM AVAILABLE
 113  GATE        SNF10                    114
 114  LEAVE       17                       126
 126  MATCH       55                       32
 130  ADVANCE                     BOTH     132   32
 132  COMPARE     X100  GE   K2400         134
 134  SPLIT                                138   150
 138  ADVANCE                     BOTH     140   142
 140  STORE       3                        155
```

```
 142  ADVANCE                               OTH  143    *2
* RECEIVE SIGNAL THAT EXAMINER HAS RETURNED FROM LUNCH
 143  GATE        SNF12                    OTH  144    *2
 144  STORE       4                             155            1000
 150  ADVANCE                               OTH  151    *52
 151  STORE       1                             155
 152  ADVANCE                               OTH  153    *2
* RECEIVE SIGNAL THAT EXAMINER HAS RETURNED FROM LUNCH
 153  GATE        SNF15                     OTH  154    *2
 154  STORE       2                             155            1000
 155  COMPARE     X100  LE    3                 32
************      NURSE-PRACTITIONER SUB-ROUTINE        *************
************      NURSE-PRACTITIONER SUB-ROUTINE        *************
************      NURSE-PRACTITIONER SUB-ROUTINE        *************
 200  GENERATE          1                       202
 202  ADVANCE                               .10 206    204
 204  ADVANCE                                   206            70    32
 206  ADVANCE                               OTH 208    *30   1
* TESTING TO DETERMINE IF A PATIENT IS READY FOR EXAMINATION
 208  COMPARE     Q2    GE    K1                209
* NURSE IS READY TO SCREEN
 209  HOLD        70                            211            1
* PATIENT READY FOR SCREENING
 211  GATE        SF21                          213
* ACTUAL SCREENING
 1    FUNCTION    RN1   C2
0.25  100   1.0   150
 213  HOLD        10                            214            1      FN1
 214  ADVANCE                               OTH 216    *30    2
 216  GATE        U25                           220            1
 220  GATE        NU25                          230
 230  SPLIT                                     240    *52
 240  ADVANCE                                   242            2
 242  GATE        NU19                          244
 244  ADVANCE                               OTH 246    *02
 246  COMPARE     X100  GE    K5400 OTH         248    *06
 248  GATE        SF16                          250
 250  COMPARE     X100  LE    K2                202
* SUB-ROUTINE----ALLOW BREAK FOR LUNCH
 252  ADVANCE                               OTH 254    *2
 254  COMPARE     X100  GE    K2400 OTH         256    *2
 256  GATE        SE15                      OTH 258    *2
 258  HOLD        19                            260            670    100
 260  STORE       15                            262            100
 262  COMPARE     X100  LE    K2                32
************      PHYSICIAN SUB-ROUTINE     ************
************      PHYSICIAN SUB-ROUTINE     ************
************      PHYSICIAN SUB-ROUTINE     ************
************      PHYSICIAN SUB-ROUTINE     ************
 391  GENERATE          1     7                 400                          PHYSIC
 400  ADVANCE                              .135 403    401
 401  ADVANCE                                   403            70    40
 403  ADVANCE                               OTH 420    *60    1
* TESTING TO DETERMINE IF A PATIENT IS READY FOR EXAMINATION
 420  COMPARE     Q3    GE    K1                440
* PHYSICIAN READY TO EXAMINE
 440  HOLD        50                            445            1
```

```
 723  ADVANCE                                   .85   735   32    1     FN8
 713  COMPARE     X100  LE    K2599                 724
 724  SPLIT                                         725   726
 9    FUNCTION    RN1   L4
.360  150   .445  300   .840  450   1.0             600
 725  ADVANCE                                       735         1     FN9
 726  ADVANCE                                 .95   735   32    1     FN9
 714  COMPARE     X100  LE    K2999                 727
 727  SPLIT                                         728   729
 10   FUNCTION    RN1   L4
.312  150   .530  300   .765  450   1.0             600
 729  ADVANCE                                       735         1     FN10
 728  ADVANCE                                 .75   735   32    1     FN10
 715  COMPARE     X100  LE    K3599                 730
 730  SPLIT                                         731   732
 11   FUNCTION    RN1   L4
.288  150   .525  300   .830  450   1.0             600
 731  ADVANCE                                       735         1     FN11
 732  ADVANCE                                 .90   735   32    1     FN11
 12   FUNCTION    RN1   L4
.320  150   .490  300   .795  450   1.0             600
 716  COMPARE     X100  LE    K4199 .875            735   32    1     FN12
 717  COMPARE     X100  LE    K4799 .895            735   32    150
 718  ADVANCE                                       735
 735  QUEUE       6                         BOTH    737   736
 737  COMPARE     X100  GE    K5400                 32
 736  ASSIGN      4     K21                         739
 739  ASSIGN      5     K5                          738
 738  SEIZE       1                         ALL     33    35    60    13
      START       3           18200

CLOCK TIME  REL        18000              ABS        18000
```

TRANS COUNTS

BLOCK	TRANS	TOTAL	BLOCK	TRANS	TOTAL	BLOCK	TRANS	TOTAL	BLOCK	TRANS	TOTAL	BLOCK	TRANS	TOTAL
1	0	120	2	0	33	3	0	120	4	0	72	5	0	33
6	0	64	7	0	0	8	0	0	9	0	0	10	0	17999
11	0	17549	12	0	17549	13	0	6	14	0	1	15	0	1
16	0	0	17	0	0	18	0	17999	19	0	17999	20	0	0
21	0	0	22	0	66	23	0	0	24	0	58	25	0	47
26	0	37	27	0	37	28	0	58	29	0	0	30	0	64
31	0	64	32	0	36707	33	0	107	34	0	0	35	0	0
36	0	107	37	0	107	38	0	0	39	0	0	40	0	0
41	0	3	42	0	0	43	0	3	44	0	3	45	0	0
46	0	0	47	0	0	48	0	0	49	0	0	50	0	107
51	0	0	52	0	0	53	0	10	54	0	0	55	0	0
56	0	0	57	0	0	58	0	0	59	0	0	60	2	107
66	0	0	67	0	0	68	0	0	69	0	0	70	0	107
76	0	0	77	0	0	78	0	0	79	0	0	80	0	107
86	0	0	87	0	0	88	0	0	89	0	0	90	0	107
91	0	0	92	0	0	93	0	0	94	0	0	95	0	59
101	1	3	102	0	56	103	0	56	104	1	3	105	0	4
111	0	0	112	0	0	113	0	0	114	0	0	115	1	107
116	1	106	117	0	0	118	0	0	119	0	0	120	0	0
121	0	0	122	0	0	123	0	0	124	0	0	125	0	105
126	0	105	127	0	0	128	0	0	129	0	0	130	0	0
141	0	0	142	14	105	143	0	0	144	0	0	145	0	0
146	0	0	147	0	0	148	0	0	149	0	0	150	0	95

```
LOC  NAME          X     Y     Z      SEL   NBA   NBB   MEAN  MOD   REMARKS   E

     JOB          22421456343 3
******            SEQUENCE TWO      SEQUENCE TWO      SEQUENCE TWO      ********
******            SEQUENCE TWO      SEQUENCE TWO      SEQUENCE TWO      ********
******            SEQUENCE TWO      SEQUENCE TWO      SEQUENCE TWO      ********
******            SEQUENCE TWO      SEQUENCE TWO      SEQUENCE TWO      ********
******            SEQUENCE TWO      SEQUENCE TWO      SEQUENCE TWO      ********
*    CLINICAL ASSISTANT---NURSE-PRACTITIONER---PHYSICIAN---CLINICAL ASSISTANT X
*    CLINICAL ASSISTANT---NURSE-PRACTITIONER---PHYSICIAN---CLINICAL ASSISTANT X
*    CLINICAL ASSISTANT---NURSE-PRACTITIONER---PHYSICIAN---CLINICAL ASSISTANT X
*    CLINICAL ASSISTANT---NURSE-PRACTITIONER---PHYSICIAN---CLINICAL ASSISTANT X
******         PEDIATRIC PATIENTS   **    **    **   PEDIATRIC PATIENTS      ********
******         PEDIATRIC PATIENTS   **    **    **   PEDIATRIC PATIENTS      ********
******         PEDIATRIC PATIENTS   **    **    **   PEDIATRIC PATIENTS      ********
 601  GENERATE                7            41          6000
 14   GENERATE          1     7            15
* GENERATE THE PATIENT SCHEDULED FOR 8:30
 10   GENERATE    1           6     BOTH   11    32    1
* GENERATE THE MORNING PATIENTS FROM 9:00 TO 11:30
 1    GENERATE    1           7     BOTH   2     32    150   0
* GENERATE THE AFTERNOON PATIENTS FROM 1:00 TO 3:00
 3    GENERATE    1           7     BOTH   4     32    150   0
 700  GENERATE                7     ALL    710   718   300   150
* GENERATOR FOR PROGRAM CLOCK
 18   GENERATE    1           7            19          1     0
 9    TABLE       MP8   0     50    70
 11   TABLE       MP2   0     50    50
 12   TABLE       M1    0     50    500
 51   QTABLE      2     0     10    50
 50   QTABLE      1     0     50    50
 52   QTABLE      3     0     10    50
 1    CAPACITY    1
 2    CAPACITY    1
 3    CAPACITY    1
 4    CAPACITY    1
 5    CAPACITY    1
 6    CAPACITY    1
 10   CAPACITY    3                 NUMBER OF EXAMINING ROOMS
 12   CAPACITY    1
 15   CAPACITY    1
 17   CAPACITY    1
 20   CAPACITY    1
 21   CAPACITY    1
 50   CAPACITY    1
 2    COMPARE     X100  LE    K1501        22
 4    COMPARE     X100  GE    K2400 BOTH   5     32
 5    COMPARE     X100  LE    K3901        22
 11   COMPARE     X100  GE    K150  BOTH   12    32
 12   SAVEX       10+   K1          BOTH   13    32
 13   COMPARE     X10   LE    K2    ,20    30    32    200   125
 15   SAVEX       50    K0                 32
* SAVEX LOCATION THAT IS PROGRAM CLOCK
 19   SAVEX       100+  K1                 32
* SUB-ROUTINE FOR ASSIGNING ON TIME APPOINTMENT ARRIVALS A HIGH PRIORITY
```

```
.170  30    .62   60    .84   80    .94   120   1.0   150
 180  ADVANCE                           200         1     FN3
* PATIENT WAITING IN ROOM FOR EXAMINATION BY M.D.
 200  QUEUE       3                     210         1
* TEST FOR M.D. READINESS TO EXAMINE
 210  GATE        U50             BOTH  215   200   1
 215  STORE       20                    230         2
 230  MARK        8                     235
* ACTUAL EXAMINATION
 4    FUNCTION    PN1   C7    ADULT APPOINTMENT  ----MD---- ONLY--------------
0.0   0.0   .046  50    .165  100   .547  150   .789  200   .933  250
1.0   350
 5    FUNCTION    RN1   C6    ADULT WALK-IN -----MD--------ONLY---------
.0    50    .126  100   .475  150   .842  200   .947  250   1.0   350
 235  HOLD        5                     240         1     FN*5
* TABULATE EXAMININIG TIME
 240  TABULATE    9                     270
* FREE ONE ROOM
 270  LEAVE       10                    390         10    8
 390  TABULATE    12                    32
************      PHYSICIAN SUB-ROUTINE     ************
************      PHYSICIAN SUB-ROUTINE     ************
************      PHYSICIAN SUB-ROUTINE     ************
 391  GENERATE          1     7         400                           PHYSICIAN
 400  ADVANCE                     .135  403   401
 401  ADVANCE                           403         70    40
 403  ADVANCE                     BOTH  420   460   1
* TESTING TO DETERMINE IF A PATIENT IS READY FOR EXAMINATION
 420  COMPARE     Q3    GE    K1        440
* PHYSICIAN READY TO EXAMINE
 440  HOLD        50                    445         1
 445  ADVANCE                           450         4
 450  GATE        NU5                   460
 460  SPLIT                             465   510
 465  ADVANCE                           466         2
 466  GATE        NU20                  470
 470  ADVANCE                     BOTH  475   400
 475  COMPARE     X100  GE    K5400 BOTH  480   403
 480  GATE        SE10                  481
 481  COMPARE     X100  LE    K100      400
* SUB-ROUTINE----ALLOW BREAK FOR LUNCH
 510  ADVANCE                     BOTH  520   32
 520  COMPARE     X100  GE    K2400 BOTH  530   32
 530  GATE        SE4             BOTH  560   32
 560  HOLD        20                    570         670   100
 570  STORE       4                     571
 571  COMPARE     X100  LE    K3        32
************ WALK-IN PATIENT INPUT SUB-ROUTINE *************
 710  COMPARE     X100  LE    K599  .730  735   32    300   50
 7    FUNCTION    RN1   D4
.295  150   .715  300   .935  450   1.0   600
 711  COMPARE     X100  LE    K1199 .125  735   32    1     FN7
 712  COMPARE     X100  LE    K1799       721
 721  SPLIT                             722   723
 8    FUNCTION    RN1   D4
.290  150   .60   300   .820  450   1.0   600
 722  ADVANCE                           735         1     FN8
```

```
 LOC   NAME          X       Y       Z       SEL    NBA    NBB    MEAN   MOD    REMARKS    E


       JOB           345421445555
******               SEQUENCE ONE        SEQUENCE ONF        SEQUENCE ONE        ********
******               SEQUENCE ONE        SEQUENCE ONE        SEQUENCE ONE        ********
******               SEQUENCE ONE        SEQUENCE ONE        SEQUENCE ONE        ********
******               SEQUENCE ONE        SEQUENCE ONE        SEQUENCE ONE        ********
******               SEQUENCE ONE        SEQUENCE ONE        SEQUENCE ONE        ********
******               SEQUENCE ONE        SEQUENCE ONE        SEQUENCE ONE        ********
*          CLINICAL ASSISTANT---PHYSICIAN---CLINICAL ASSISTANT                          A
*          CLINICAL ASSISTANT---PHYSICIAN---CLINICAL ASSISTANT                          A
*          CLINICAL ASSISTANT---PHYSICIAN---CLINICAL ASSISTANT
*          CLINICAL ASSISTANT---PHYSICIAN---CLINICAL ASSISTANT                          X
******     ADULT PATIENTS     *  *  *  *  *  * *   ADULT PATIENTS        ********
******     ADULT PATIENTS     *  *  *  *  *  * *   ADULT PATIENTS        ********
******     ADULT PATIENTS     *  *  *  *  *  * *   ADULT PATIENTS        ********
 14    GENERATE         1       7                  15
* GENERATE THE PATIENT SCHEDULED FOR 8:30
 10    GENERATE      1              4       BOTH   11     32     1
* GENERATE THE MORNING PATIENTS FROM 9:00 TO 11:30
 1     GENERATE      1              3       BOTH   2      32     150    0
* GENERATE THE AFTERNOON PATIENTS FROM 1:00 TO 3:00
 3     GENERATE      1              3       BOTH   4      32     150    0
 700   GENERATE      1              1       ALL    710    718    300    150
* GENERATOR FOR PROGRAM CLOCK
 603   GENERATE                     7              41            6000
 18    GENERATE      1              1              19            1      0
 20    CAPACITY      1
 8     CAPACITY      1
 7     CAPACITY      1
 50    CAPACITY      1
 16    CAPACITY      1
 1     CAPACITY      1
 2     CAPACITY      1
 6     CAPACITY      1
 10    CAPACITY      2
 4     CAPACITY      1
 9     TABLE         MP8     0      50      50
 10    QTABLE        3       0      50      50
 11    QTABLE        1       0      50      50
 12    TABLE         M1      0      50      100
 2     COMPARE       X100    LE     K1501          22
 4     COMPARE       X100    GE     K2400 BOTH     5      32
 5     COMPARE       X100    LE     K3901          22
 11    COMPARE       X100    GE     K150    BOTH   12     32
 12    SAVEX         10+     K1             BOTH   13     32
 13    COMPARE       X10     LE     K2      .20    30     32     200    125
 15    SAVEX         50      P6                    32
* SAVEX LOCATION THAT IS PROGRAM CLOCK
 19    SAVEX         100+    K1                    32
* SUB-ROUTINE FOR ASSIGNING ON TIME APPOINTMENT ARRIVALS A HIGH PRIORITY
 22    ADVANCE                              .10    24     32
 6     FUNCTION      RN1     C16      ADULT
0.0    90     .040   180    .090   420    .126   493    .170   540    .220   563
.280   573    .480   588    .577   593    .686   610    .760   615    .807   660
```

```
.860  700   .890   740    .940   900    1.0    1400
 24   ASSIGN       2      FN6           BOTH   25     28     1      FN6
 25   COMPARE      P2     LE     K680   BOTH   26     28
 26   COMPARE      P2     GE     K400          27
 27   PRIORITY     5                           28
 28   QUEUE        5                    BOTH   29     30
 29   COMPARE      X50    GE     K4            32
 30   ASSIGN       4      K20                  6
 6    ASSIGN       5      K4                   31
 31   SEIZE        1                    ALL    33     35     12
 32   TERMINATE
* STOP PATIENT INPUT AT 15 MIN. BEFORE CLOSING TIME
 33   COMPARE      X100   LE     K5250         36
* ALLOW PATIENTS TO ENTER IF NONE ARE WAITING
 34   COMPARE      Q1     NE     K0            36
* SCHEDULE A NEW APPOINTMENT FOR A PATIENT
 35   RELEASE      1                    BOTH   38     32     22
 36   RELEASE      1                    ALL    37     39
* STOP ALL PATIENT INPUT AT CLOSING TIME
 37   COMPARE      X100   LE     K5400         50
* SUB-ROUTINE TO ALLOW SYSTEM TO CLEAR AT THE END OF EACH DAY
* AND RESTART THE SYSTEM FOR ANOTHER DAY
 39   TERMINATE
 38   STORE        50                          32
 41   SAVEX        100    K0                   43
 43   SAVEX        10     K0                   44
 44   SAVEX        50     K1                   500
 500  TERMINATE    R
 50   SPLIT                                    60     70
 70   SPLIT                                    80     90
* STOP PATIENTS AT 12:00 AND RESTART WHEN M.D. RETURNS LUNCH
 80   COMPARE      S1     E      S2            115
 90   ADVANCE                           BOTH   95     32
 95   COMPARE      X100   GE     K2400  BOTH   101    102
 101  STORE        1                           105           1000
 102  ADVANCE                                  103
* RECEIVE SIGNAL THAT EXAMINER HAS RETURNED FROM LUNCH
 103  GATE         SNE4                 BOTH   104    32
 104  STORE        2                           105           1000
 105  COMPARE      X100   LE     K3            32
* TESTING FOR A ROOM AVAILABLE
 115  ADVANCE                                  116
 116  ENTER        16                          125           1
 125  GATE         SNF10                       126
 126  LEAVE        16                          142
 142  MATCH        151                         32
* WAITING ROOM
 60   QUEUE        1                    BOTH   53     150
 53   COMPARE      X100   LE     K10           32
* RECEIVES SIGNALS--ONE ROOM AVAILABLE--EXAMINER NOT AT LUNCH-----
 150  GATE         M142                        151
 151  HOLD         10                          152           1
 152  MATCH        142                         170
* REDUCES NUMBER OF AVAILABLE ROOMS BY ONE
 170  ENTER        10                          180
* PREPARE PATIENT FOR EXAMINATION
 3    FUNCTION     RN1    C5
```

APPENDIX IV

MULTIPLE T TEST ANALYSIS

The analysis by means of multiple two-sample t tests of the study data presented in Table 15 has been presented for reader interest only. The results of the analysis carried out in this appendix have been confined solely to this appendix and do not appear in any other section.

Neither the two-sample t tests nor the Mann-Whitney U tests used to support the t tests can be considered independent and hence, as stated by Miller and Freund (29), "it would be virtually impossible to assign an overall level of significance to such procedures." Consequently, the overall results obtained from this analysis cannot be said to be statistically valid.

A4.1 Analysis

The first step in the analysis of the study data listed in Table 19 was the calculation of the mean and standard error for each cell. The different cells or groups of cells were then tested for the null hypothesis of equality of means against the alternative of inequality of means by use of two-sample t tests supported by Mann-Whitney U tests (referred to as rank sum tests) when applicable. The arbitrary significance level of .05 was used for both tests.

The effects are analyzed and indicated in Tables 19, 20, and 21. These tables are as follows: Table 19 shows the sequence effect for both the pediatric and

Table 19. Sequence Effect - Combined Data

	Adult Combined Rooms	Pediatric Combined Rooms
Sequence One $\bar{x}$ - s.e.$\bar{X}$	89.1 - .34	93.7 - .69
Sequence Two $\bar{y}$ - s.e.$\bar{x}$	92.3 - .63	93.5 - .72
$\bar{x} - \bar{y}$	-3.2	-.2
s.e. $(\bar{x} - \bar{y})$	.91	1.19
t	3.51	.25
p (t-test)	.0005	* .40, .50

Rejection Level $\alpha = .05$

* Not significant, hypothesis $(\mu_1 = \mu_2)$ cannot be rejected.

Note: These tests were performed to investigate the overall effect of sequence.

Table 20. Sequence Effect

	Adult			Pediatric		
	2 Rooms	3 Rooms	4 Rooms	2 Rooms	3 Rooms	4 Rooms
Sequence One						
$\overline{X} - s.e_x$	86.2-1.48	89.0-.43	92.0-.84	92.1-1.42	93.3-1.00	95.8-1.14
Sequence Two						
$\overline{Y} - s.e_y$	80.6-.69	97.6-1.4	98.6-1.45	81.8-1.62	96.3-.92	102.3-2.23
Sequence One vs. Sequence Two						
$\overline{X} - \overline{Y}$	5.6	8.6	6.6	10.3	-3.0	-6.5
$s.e(\overline{X} - \overline{Y})$	1.63	1.46	1.67	2.15	1.35	2.5
$\pm$ Value	3.43	5.89	3.45	4.79	-2.22	-2.6
p(t-test)	.005, .001	.0005	.0005	.0005	.025, .01	.01, .005
P(Rank Sum)	.01	.001	.001	.001	.025	.025

Rejection Level $\alpha = .05$

Note: These tests were performed to investigate the sequence effect at each level of numbers of rooms.

Table 21. Room Effect

	Adult			Pediatric		
	Sequence One			Sequence One		
	Rooms 2 vs 3	Rooms 3 vs 4	Rooms 2 vs 4	Rooms 2 vs 3	Rooms 3 vs 4	Rooms 2 vs 4
$\overline{x} - \overline{y}$	2.8	3.0	5.8	1.20	2.50	3.70
s.e$(\overline{x} - \overline{y})$	1.55	.95	1.70	1.74	1.51	1.82
t	1.81	3.16	3.44	.69	1.66	2.03
p(t-test)	.05, .025	.005, .01	.005, .01	*.30, .20	*.10, .05	.05, .025
P(Rank Sum)	*p > .05	*p > .05	.001, .01	*p > .05	*p > .05	p = .05
	Sequence Two			Sequence Two		
$\overline{x} - \overline{y}$	17.0	1.0	18.0	14.5	6.00	21.50
s.e$(\overline{x} - \overline{y})$	1.56	2.01	1.60	1.41	2.41	2.76
t	10.90	.50	11.25	10.23	3.49	7.79
p(t-test)	.0005	*.40, .30	.0005	.0005	.025, .01	.0005
P(Rank Sum)	p = .001	*p > .05	p = .001	p .001	.05, .025	p = .001

Rejection Level $\alpha = .05$

*Not significant, hypothesis $(U_1 = U_2)$ cannot be rejected.

Note: These tests were performed to investigate the number of rooms effect on each sequence.

adult units and the effect with all data combined. (It was not necessary to use the rank sum test for analysis in this table since for large samples the t statistic is assymptotically normally distributed by the central limit theorem whether or not the actual samples are normally distributed.) Table 20 records the sequence effect at the three room levels for both units. Table 21 shows the room effect at the two sequence levels for both units.

A4.2 Statistical Analysis Procedures and Rationale

The mean and standard error were calculated for each cell (six for each 2 x 3 unit design, 12 total for both units) in Table 15 by the following standard statistical formulas:

Mean:

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n} \tag{2}$$

Standard Error:

$$\text{s.e.} = \sqrt{\sum_{i=1}^{n} \frac{(X_i - \bar{X})^2}{n(n-1)}} \tag{3}$$

Where: X_i = an individual data point.

n = 10, the number of data points.

The two above statistics are given for each individual cell in Table 15 in that cell.

The following formula from Walker and Lev[28] was used for the calculation of the t statistic:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{1}{n_1} \pm \frac{1}{n_2}} \sqrt{\frac{\sum_{i=1}^{n} (X_{1_i} - \overline{X}_1)^2 + \sum_{i=1}^{n} (X_{2_i} - \overline{X}_2)^2}{n_1 + n_2 - 2}}} \tag{4}$$

The significance level was then looked up in standard statistical tables for the t distribution using the calculated value of t and ($n_1 + n_2 - 2$) degrees of freedom. The resultant levels are presented in Tables 19, 20, and 21.

The t test assumes normality and equality of variance ($\sigma_1^2 = \sigma_2^2$). Both of these assumptions were made for testing the null hypothesis of equal means and the t test was used even though the equality of variance did not hold at the .01 level (ratio ${s.e_1}/{s.e_2} = 2.6$ at $\alpha = .01$) in two cases (adult sequence one vs. sequence two at the three room level and adult two rooms vs. adult three rooms at the sequence one level). Normality was not checked. However the t test is known to perform reasonably well when the assumption of normality does not hold.

In all applications when $n_1 = n_2$ the preceding formula for t simplifies to:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \tag{5}$$

The formulas for S_1 and S_2 are then as follows:

$$S_1^{\,2} = \frac{\sum_{i=1}^{n_1} (X_{i1} - \overline{X}_1)^2}{n_1 - 1} \tag{6}$$

$$S_2^{\,2} = \frac{\sum_{i=1}^{n_2} (X_{i2} - \overline{X}_2)^2}{n_2 - 1} \tag{7}$$

The t distribution approximates a normal distribution when n_1 and n_2 are large. When n_1 and n_2 are small and both samples are approximately normally distributed, and S_1 and S_2 do not differ significantly, t has the t distribution with $n_1 + n_2 - 2$ degrees of freedom. If S_1 and S_2 do differ significantly then t has the t distribution with degrees of freedom determined by the formula below:

$$\left[\left(\frac{S_1^{\,2}}{n_1}\right)+\left(\frac{S_2^{\,2}}{n_2}\right) \div \left(\left(\frac{1}{n_1+1}\right)\left(\frac{S_1^{\,2}}{n_1}\right)^2 + \left(\frac{1}{n_2+1}\right)\left(\frac{S_2^{\,2}}{n_2}\right)^2\right)\right] - 2 \tag{8}$$

S_1 and S_2 may be found to differ significantly if the F ratio $F = S_1^{\,2}/S_2^{\,2}$ is significant at the .05 level with $n_1 - 1$ degrees of freedom in the numerator and $n_2 - 1$ degrees of freedom in the denominator (Walker and Lev,[28] pp. 155 – 159).

The Mann-Whitney U test referred to as the rank sum test was used in addition to the t test because the rank sum test does not assume approximate normality as does the t test. The rank sum test is, however, less precise than the t test. The procedure used for applying the rank sum test is that outlined in Siegel.[30] The rank sum test was used in conjunction with the exact U tables for small samples found in either Siegel[30] or the Handbook of Statistical Tables by Owen.[31]

In both tests, .05 was arbitrarily selected as the level at which the null hypothesis of equal means could not be rejected. A level any greater than .05 would have been subject to questionable significance. (It is important to note the exact values of the rank sum were not calculated when $P > .05$ since the test had already indicated a similarity of means at that level.)

The two tests were found to agree in all but two cases (adult sequence one level, two rooms vs. three rooms, and three rooms vs. four rooms) when the rank sum indicated that the null hypothesis of equal means could not be rejected. The statistical significance of the t test because of its greater precision was given priority in these two instances over the rank sum test and the means were assumed to be different.

A4.3 Findings of Analysis

The specific findings of this analysis of data indicated, concerning the addition of the nurse (sequence effect) to a health team medical unit and varying the number of examining rooms per medical unit, the following generalizations:

1. The addition of the nurse was statistically significant at all room levels for both units. The volume of patients who could be served by a team was reduced at the two room level by the nurse addition but was increased at the three and four room levels by the nurse addition.
2. The effect upon patient volume of varying the number of examination rooms per medical unit was found statistically significant for the adult unit in sequence one at all room levels incréases and in sequence two and only at the increase from two to three rooms and for the pediatric unit only in sequence two at both the increases from two to three and from three to four rooms. In all cases the effect of increasing from two to four rooms was significant even though the mean patient volumes with three and with four rooms was significantly different in only one case.
3. When all room data were combined, the sequence effect was found significant for only the adult medical unit.

From the above statements the following inferences can be drawn: (1) that under the current ASCHC health team medical unit area layout (two rooms), the effect of adding a nurse practitioner to the medical units would be to reduce the patient volume by two to five per cent, (2) that if a medical unit is provided with more than two rooms (three of four rooms) the addition of the nurse will increase the patient volume by two to ten per cent, (3) that increasing the number of rooms from two to three is effective in increasing patient volume only if the nurse is also added to the medical unit with the extent of the increase being about five per cent, and (4) that the addition of a fourth room will increase the patient volume only in the pediatric sequence two and the adult sequence one. (In all cases increasing from two to four rooms increases the patient volume; however, since patient volume is affected by the increase from three to four rooms in only the above case, the two vs. four analysis was largely meaningless.)

It is interesting to note at this point that the above findings were similar to those obtained by the use of ANOVA and Duncan's Multiple Range Test. The results of the ANOVA and Duncan's Multiple Range Test had an overall significance level of $\alpha = .05$. The overall significance level of the multiple t and rank sum tests could not be assigned. Thus the similarity can only be said to be due to chance and not to the statistical accuracy of the procedure outlined in this appendix.

BIBLIOGRAPHY

1. Walter Johnson and Leonard Rosenfield, "Factors Affecting Waiting Time in Ambulatory Care Services," Health Services Research, Winter 1968, Vol. 3, No. 4, pp. 286-295.

2. Robert Fetter and John Thompson, "Patients' Waiting Time and Doctors' Idle Time in the Outpatient Setting," Health Services Research, Summer 1966, Vol. 1, No. 1, pp. 66-90.

3. Eduardo A. Villegas, "Outpatient Appointment System Saves Time for Patients and Doctors," Hospitals, April 16, 1967, Vol. 41, No. 8, pp. 52-59.

4. William J. William, Richard Corvert, and James Steele, "Simulation Modeling of a Teaching Hospital Outpatient Clinic," Hospitals, Nov. 1, 1967, Vol. 41, No. 21, pp. 71-75.

5. Joseph Balintfy, "A Stochastical Model for the Analysis and Prediction of Admissions and Discharges in Hospitals," Proceedings of the Sixth International Meeting of the Institute of Management Science, 1963.

6. Jay Goldman, Allan Knappenberger, and J. C. Eller, "Evaluating Bed Allocation Policy with Computer Simulation," Health Services Research, Summer 1968, Vol. 3, No. 2, pp. 119-129.

7. Gordon Robinson, Paul Wing, and Louis Davis, "Computer Simulation of Hospital Patient Scheduling Systems," Health Services Research, Summer 1968, Vol. 3, No. 2, pp. 130-141.

8. Shlomo Barnoon and Harvey Wolfe, "Scheduling a Multiple Operating Room System: A Simulation Approach," Health Services Research, Winter 1968, Vol. 3, No. 4, pp. 272-285.

9. J. Goldman and H. Knappenberger, "Simulation of Operating Room Scheduling Policies," Proceedings of the National Meeting of the American Institute of Industrial Engineers, 1968, pp. 148-152.

10. J. Goldman and H. Knappenberger, "An Evaluation of Operating Room Scheduling Procedures," Hospital Management, April 1969, Vol. 107, No. 4, pp. 40-51.

11. Alan Handyside and David Morris, "Simulation of Emergency Bed Occupancy," Health Services Research, Fall-Winter 1967, Vol. 2, No. 3, pp. 287-297.

12. Kerry Kilpatrick and Louis Freund, "A Simulation of Oxygen Inventory at a Community General Hospital," Health Services Research, Fall-Winter, 1967, Vol. 2, No. 3, pp. 298-305.

13. Eric Leighton and Peter Headly, "Computer Analysis of Length of Stay," Hospital Progress, Vol. 49, No. 4, April 1968, pp. 67-70.

14. John D. Thompson and Robert B. Fetter, "The Application of Simulation to Hospital Planning," Proceedings on Simulation in Business and Public Health, First Annual Conference of American Statistical Association and Public Health Association of New York City, 1966, pp. 205-209.

15. John L. Cooley, J. B. Hallan, and A. H. Packer, "A Simulation Study of Alternative Medical Support Systems for More Disaster Casualties," Research Triangle Institute, Research Triangle Park, North Carolina, 1967.

16. Paul A. Bonner, "The Application of Computer Simulation Techniques to an Emergency Room Service," Unpublished Thesis, Yale University, New Haven, Conn., 1968.

17. Fredric D. Kennedy, The Development of a Community Health Service System, Research Triangle Institute, Operations Research and Economics Division, Research Triangle Park, North Carolina, 1967.

18. Bernice B. Brown, Delphi Process: A Methodology Used for the Elicitation of Opinions of Experts, the RAND Corporation, Santa Monica, Cal., 1965, pp. 3925.

19. Olaf Helmer and N. H. Rescher, "On the Epistemology of the Inexact Sciences," Management Science, Vol. 6, 1959, pp. 25-52.

20. Norman Dalkey and Olaf Helmer, "An Experimental Application of the Delphi Method to the Use of Experts," Management Science, Vol. 9, 1963, pp. 458-467.

21. Norman Dalkey, Delphi, P-3704, the RAND Corporation, Santa Monica, Cal., 1967.

22. Bernice B. Brown and Olaf Helmer, Improving the Reliability of Estimates Obtained from a Consensus of Experts, P-2986, the RAND Corporation, Santa Monica, Cal., 1964.

23. T. Gordon and Olaf Helmer, Report on a Long Range Forecasting Study, R-353, the RAND Corporation, Santa Monica, Cal., 1964.

24. Robert Campbell, A Methodological Study of Expert Utilization in Business Forecasting, Unpublished PH.D. dissertation, University of California, L. A., 1966.

25. M. Adelson, M. C. Alkin, C. Carey, and O. Helmer, "Planning Education for the Future: Comments on a Pilot Study," American Behaviorial Scientist, March 1967, pp. 1-12.

26. Norman Dalkey, The Delphi Method: An Experimental Study of Group Opinion, RM-5888, the RAND Corporation, Santa Monica, Cal., 1969.

27. Edward V. Krick, Methods Engineering Design and Measurement of Work Methods, John Wiley and Sons, Inc., New York, N. Y., 1966.

28. Walker and Lev, Statistical Inference, Henry Holt and Co., New York, 1953.

29. I. Miller and J. E. Freund, Probability and Statistics for Engineers, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1965, p. 279.

30. S. Siegel, Non-Parametric Statistics for the Behavioral Sciences, McGraw-Hill Book Co., New York, 1956.

31. C. R. Hicks, Fundamental Concepts in the Design of Experiments, Holt, Rinehart and Winston, New York, 1966.

32. A. J. Duncan, Quality Control and Industrial Statistics, Richard D. Irwin, Inc., Homewood, Illinois, 1955.

33. D. B. Duncan, "Multiple Range and Multiple F Tests," Biometrics, No. 11, 1956.

Other References

1. Bevan, F. M., and G. F. Draper, "Sampling Problems in Studies of General Practice," Medical Care, Vol. 3, No. 3, July-September, 1965, pp. 168-179.

2. Fetter, R. B., and J. D. Thompson, "The Simulation of Hospital Systems," Operations Research, Vol. 13, 1965, pp. 689-711.

3. Flagle, D. C.,"Operations Research in the Health Services," Operations Research, Vol. 10, 1962, pp. 591.

4. Flagle, D. C., "The Problem of Organization for Hospital Inpatient Care," Management Sciences: Models and Techniques, Vol. 2, 1960, pp. 275-287.

5. Helmer, Olaf, Systematic Use of Expert Opinions, P-3721, the RAND Corporation, Santa Monica, Cal., 1967.

6. March, Joseph D., and John R. Freeman, Anesthesia Task Analysis and Simulation, Technical Report No. 1, Health Systems Research Division, J. Hillis Miller Health Center, University of Florida, Gainesville, Fla.

7. McKinney, Gene R., Patient Appointment Plans in Family Medical Practice, Unpublished Thesis, 1969, University of Florida, Gainesville, Fla.

8. Trevino, Jose, Scheduling in a Rehabilitation Center, Unpublished Thesis, 1963, Case Institute of Technology, Cleveland, Ohio.

9. Young, J. P., A Queuing Theory Approach to the Control of Hospital Inpatient Census, Unpublished PH. D. Dissertation, 1962, the Johns Hopkins University.